CALIFORNIA FISH AND GAME

"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

VOLUME 46 JULY, 1960 NUMBER 3

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CALIFORNIA FISH AND GAME

VOLUME 46 JULY, 1960 NUMBER 3

Published Quarterly by the
CALIFORNIA DEPARTMENT OF FISH AND GAME
SACRAMENTO

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DEPARTMENT OF FISH AND GAME

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THE WOOD DUCK IN CALIFORNIA WITH SPECIAL REFERENCE TO THE USE OF NEST BOXES[1]

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INTRODUCTION

Aside from hunting season restrictions, there has been little effort during the last half century bent toward the study and management of the wood duck *(Aix sponsa)* in California. The wood duck now holds a position of secondary importance within the State. This is due to the rather limited population and to the bag limit restriction of one bird, two factors which reduce its utility as a hunting species. In all probability the wood duck will always remain secondary to other species of waterfowl in California and will need some type of protection and assistance to maintain its present level.

While compiling the early history of the wood duck, it was found that its status varied greatly according to the observer. Just how numerous the wood duck was during the early settlement of California is unknown, but it was reported to be common and widespread from the San Joaquin Valley northward.

The wood duck was fairly abundant after 1850. Kemerly (1859) recorded the species as abundant in the vicinity of San Francisco in February of 1854. Fisher (1920) quoted Belding as reporting that when he moved to Marysville in 1862 the wood duck was very common along the Feather River and was a continual resident in that area. Mailliard (1911) reported that it was common in Marin and Sonoma Counties in the 1870's. Townsend (1887) stated that the wood duck was a common and comparatively well distributed species and it was observed in quite large flocks along the lower McCloud River at various times throughout the fall and winter. Grinnell and Bryant (1914) wrote that the wood duck was formerly common and well distributed throughout the lowlands west of the Sierra Nevada Mountains.

The first game law in California was passed in 1852 and protected elk, deer, antelope, quail, mallard and wood duck for six months of the year. This law applied to only 12 counties, most of which were submarginal habitat as far as the wood duck was concerned.

The reason for this restriction on the wood duck was quite vague since at the same time it was considered to be abundant. This first game law did little to protect the game species it covered because at the time there were no game wardens in State employment to enforce the legislation. Apparently market hunting, especially for the valuable highly colored feathers of the male, brought about this early restriction.

[1] Submitted for publication March, 1960. A contribution of Federal Aid in Wildlife Restoration Project W-30-R, "Waterfowl Investigation."

At the turn of the century the wood duck population was declining in numbers. Due to the lack of proper law enforcement, market hunting was continued. Draining and reclaiming marshlands for agricultural purposes aided in the decline. Dredging for gold along the rivers was another factor in the decline. Both land reclamation and dredging destroyed the riparian habitat frequented by the birds. The wood duck was reported to be on the verge of extinction by 1914. Grinnell (1915) reported that the wood duck was then rather rare as a resident in the Sacramento and San Joaquin Valleys and westwardly toward the coast.

Destruction of habitat and overshooting was the general trend throughout the nation. The wood duck population became depleted to such an extent that when Congress passed legislation in 1913 to protect migratory waterfowl, the wood duck was given complete protection for five years. More protection was given the species when the Migratory Bird Treaty between the United States and Great Britain was signed in 1918, devoting Article IV to the special protection of the wood duck and eider duck. Complete protection was extended to the wood duck until 1942, when one duck was allowed in the hunter's bag limit. Under this protection the wood duck increased in California as is shown by a report (Anon. 1930) which stated "A marked increase of wood ducks has been noted in California during the past few years. This species has been protected by law everywhere since the adoption of the Migratory Bird Treaty, and the good results have been apparent in many parts of the country. One warden reports a concentration of 5,000 wood ducks congregated on Lake Almanor, Plumas County, and another concentration is reported from the Butte Creek section, Butte and Sutter Counties, where several thousand wood ducks were said to have wintered."

Stoner (1940) reported that by 1939 wood ducks had increased in abundance in favorable areas along creeks in Napa and Solano Counties.

The protection given the wood duck from hunting resulted in a general increase, but failed to return the species to its original numbers in most places. More and more land was drained and reclaimed. River channels were straightened, eliminating the wooded oxbows frequented by the birds. Mature oaks, sycamores and willows, trees most likely to have nest cavities (Fig. 1) were cut and destroyed. A shortage of nest sites throughout California was the result. This condition in California paralleled a similar situation that existed throughout the nation. It was at this time that the development of artificial nest boxes occurred. The boxes proved to be successful in wood duck management and many thousands have been installed throughout the nation.

OBJECTIVES

The primary objective of this survey was to obtain data regarding the success of a program of nest box installation. The survey was meant to be a pilot study, with limited scope, aimed toward presenting recommendations for use in guiding a large scale nest box program, in the event such a program proved feasible in California. A secondary objective was the development of an adequate method of determining the yearly status of the wood duck in California.

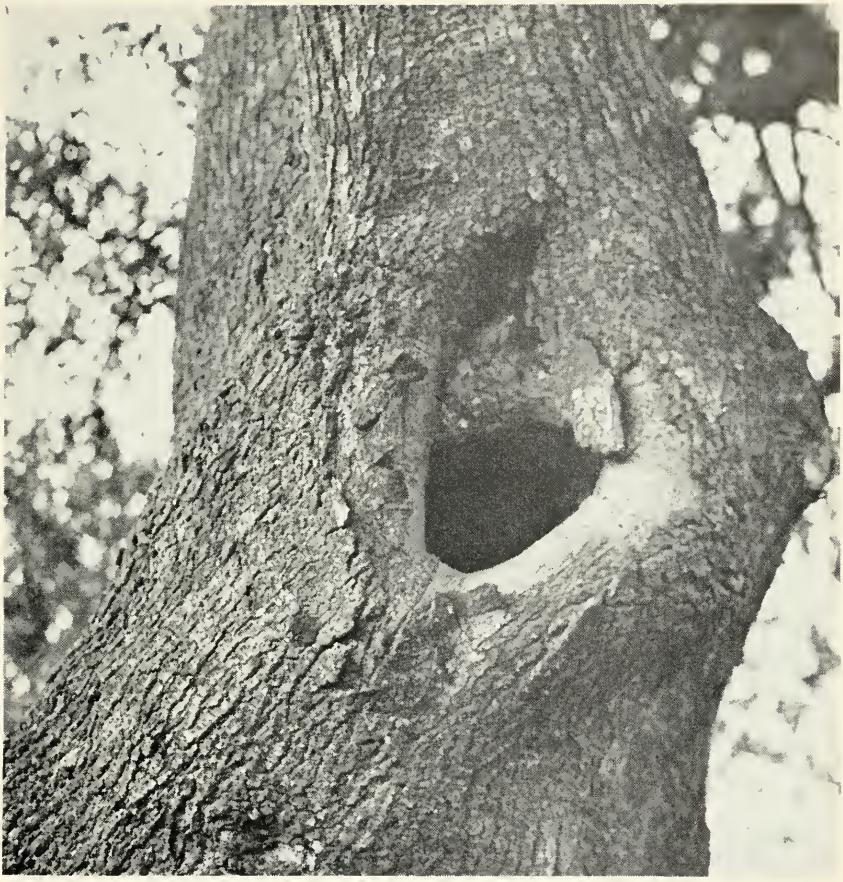

FIGURE 1. Wood ducks do not nest on the ground, instead they select natural hollows or cavities in trees.

PROCEDURE

The following is a list of terms and definitions which have come into common usage during the study. This explanation may help to clarify some of the data in this report.

Site: Each individual unit or area in which nest boxes are located. A site may contain one or more boxes.

Location: The tree or pole to which the box is attached.

Functional: Any box in a condition to be used by a wood duck or other animal.

Nonfunctional: Any box which was considered unsuited for wood duck usage. Some examples of boxes which were considered nonfunctional were those with covers missing, flooded, split badly, or concealed by vegetative growth.

Wood Duck Usage: Wood duck usage was considered to have occurred if one or more eggs were laid in the box.

FIGURE 2. A shady bank provides a loafing spot for the male as he waits for the female during the early stage of incubation. *(Photograph by F. Dale Horn.)*

Percent Usage: The number of boxes used by wood ducks in relation to the number of functional boxes checked.

Double Usage: A box in which one female wood duck hatched off a clutch with the young leaving the box, and the same box was used again during the same season by another female as a nest site. These boxes were recorded as two boxes used by wood ducks in computing percent of use.

Successful Box: Any box from which one or more wood duck eggs hatched with ducklings leaving the box.

Percent Successful: The relationship between the number of successful boxes and the total number of boxes used by wood ducks.

Other Usage: All usage other than that by wood ducks is included in other usage. This included boxes where there was evidence that an animal had entered the box to den, roost, nest or seek food.

No Usage: If no evidence was found of usage by wood ducks or other animals, the box was listed as unused.

The procedure used in installation of boxes, explained in the following paragraphs, may save others considerable experimenting in working out satisfactory methods.

It is impossible to list all areas where a wood duck will locate. The way to insure usage is to install the boxes in areas where the ducks have been known to nest. Nest boxes are needed most where the number of wood ducks is greater than the number of nest sites available.

FIGURE 3. Slow moving streams and small ponds subject to little water fluctuation provide natural foods and cover for broods. *(Photograph by F. Dale Horn.)*

FIGURE 4. Butte Slough in Sutter County is typicol of streams and rivers in the Central Volley inhabited by wood ducks.

Therefore, the first step in placement of boxes is to determine if wood ducks already inhabit the area in which the boxes are to be placed. Consulting landowners, sportsmen, fish and game personnel working in the area, or aerial or ground reconnaissance are usually good meth-

FIGURE 5. Ideal habitat in Shasta County. The addition of nest boxes in areas such as these increase the production of wood ducks.

ods of discovering if wood ducks occur in a specific area during the nesting season.

The best locations for boxes are in open stands of trees along small streams and ponds. Wood ducks frequent the quiet waters of sloughs, old river channels, ponds and waterways where oaks, willows and cottonwoods shade the banks and furnish nest cavities. An important need of the wood duck is an area adjacent to the nesting site which provides resting and feeding cover. In most cases, the birds prefer the smaller water areas to the larger lakes and rivers. Boxes should be installed as close to the water areas as possible. Generally, the greater the distance a wood duck nests from water, the greater the hazard faced by the young in their travel from the nest to the nearest water. Figures 2-7 illustrate various habitats utilized by the wood duck.

Since wood ducks do not appear to be particularly adept at locating nest cavities, the boxes should be placed in areas where they can be seen easily by the ducks. All vegetation which conceals the box should be cut away at the time the box is installed.

The height of the box above the ground was not considered too important as long as it was higher than 10 feet. Boxes placed above 10 feet in trees which were devoid of limbs below the boxes proved to have less molestation and human interference. Such a situation, however, required a ladder or climbers and safety belt for the person checking the box for usage.

FIGURE 6. Dredger ponds occur along the western slope of the Sierra foothills but many lack nest cavities, which makes these ponds ideal for the installation of nest boxes.

FIGURE 7. This small pond in Marin County was considered ideal habitat lacking only nest cavities. Two pair of wood ducks moved in and nested immediately after the installation of two boxes.

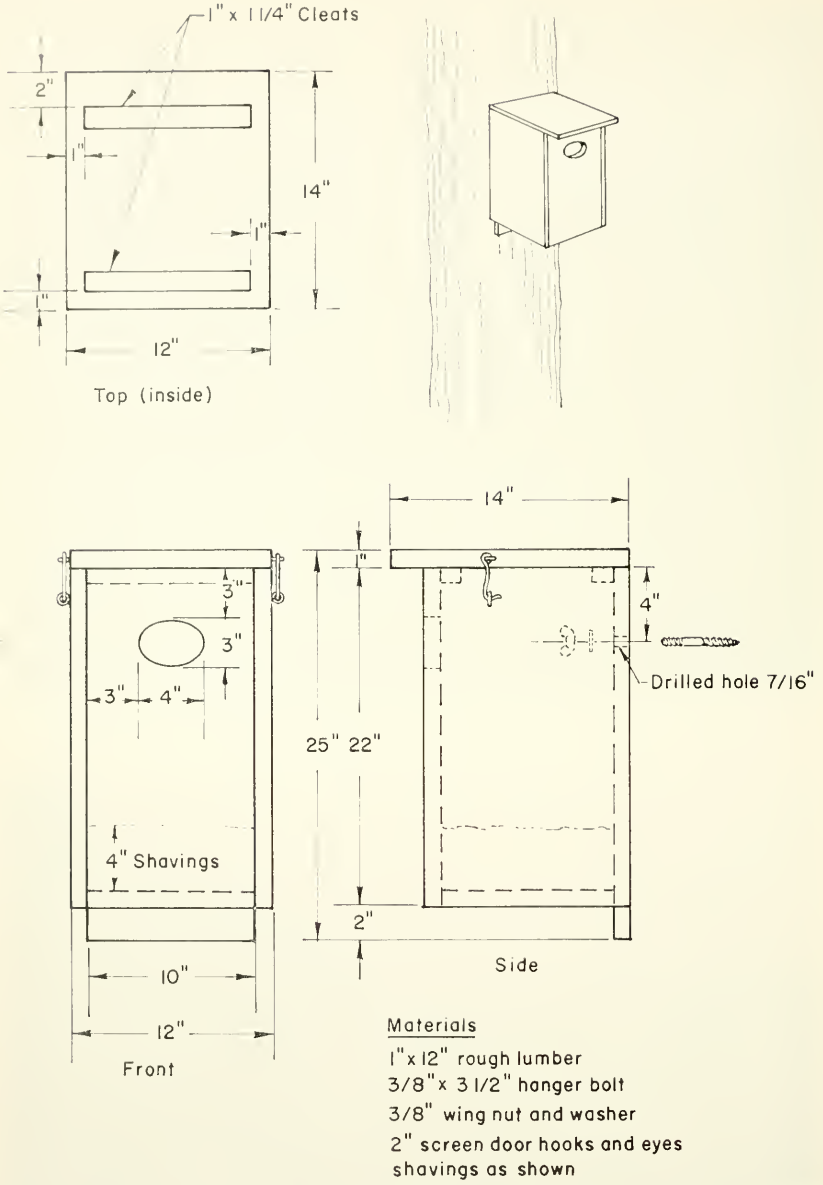

FIGURE 8. Plan of wood duck nest box. The elliptical entrance usually eliminates pilfering of the nest by racoons. *(Drawn by Cliffa Corson.)*

The boxes used were patterned after the U.S. Fish and Wildlife Service design. Two sizes were used during the study. One size was 12 inches square and 24 inches long and the other was 10 inches square and 22 inches long (Figure 8). There was no definite preference shown by the wood ducks for either size of box. By utilizing the smaller boxes, the cost of materials was reduced.

The boxes were constructed of one-inch rough redwood lumber. The rough surface of the lumber was an aid to the young in climbing out of the box. Redwood was selected because of its resistance to weather and rotting, and because it was as cheap or cheaper than rough pine or fir. However, it was more susceptible to splitting.

The cost per unit at the time of construction during this study was $1.05 for the 22-inch and $1.24 for the 24-inch boxes. This cost included the hanger bolt and hardware, but not labor. The cost could be reduced by buying the material in larger lots.

The box was attached to the tree by a hanger bolt. The box was hung on the bolt through the hole bored in the back. The wingnut and washer drew it tightly to the tree. The wingnut could be loosened to relieve pressure as the tree grew. This method of attachment proved successful and simplified installation for the installer. The nesting box should be firm and any movement kept to a minimum. A nail through the lower two inches of the back of the box was used to steady it, if needed. Boxes hanging loosely were usually rejected by the female.

Potential nest box sites were evaluated with regard to their suitability as wood duck habitat. The factors considered were available food, nest cover, cover for broods, loafing cover and general waterfowl usage. Most of the boxes were installed during the late winter, a practice which enabled the crew to place the boxes above flood or high water levels; however, it necessitated evaluating some of the above factors, such as food and brood cover, at the time of the first box check in the spring.

A box of sound construction, securely fastened to a tree or pole in a suitable location, were important factors. The personnel checking the boxes, by noting the areas and factors of maximum success, gained experience of great value for use in the erection of additional boxes. This experience can eliminate wasted effort resulting from too many boxes placed in unsuitable sites. Better success will result if the men engaged in the program are familiar with the wood duck's preferences for nesting sites.

When a box was installed, a field data sheet was filled out recording general location, installation site, method of installation and rating of the area as wood duck habitat. Such data as tree species, height of box, and direction of hole were recorded and proved valuable as an aid in relocating boxes which were difficult to find. A map of the box location was drawn at the time and any useful information was put on the map. The maps were redrawn later and added to a permanent file to be used during subsequent box checks. Each box was numbered to aid in collection of data for the individual nest box history. The boxes also were stenciled with information designed to forestall any human molestation resulting from curiosity or vandalism (Figure 9).

All boxes were checked twice during the season. The first inspection was in early May and coincided for the most part with the peak of the nesting season. The nesting season was slightly earlier in the southern parts of the range, a condition which allowed the personnel checking the boxes more time to inspect all the boxes.

FIGURE 9. Wood duck nest box showing box number and stencilled information designed to keep human molestation at a minimum.

The second check was made in July at which time the nesting season was considered complete. Few, if any, nests were active after July. The field work was considered complete when the last check was finished.

During the first check, a nest card, of the Unisort Analysis type, was made out for each box and pertinent data recorded on the card. The same card was used also on the second check. A functional box was checked to determine usage. The boxes which were nonfunctional were repaired or replaced.

The nests were examined to determine the number of eggs present and whether they were being incubated. The amount of down present was recorded, as this usually gave an indication of the stage of incubation.

Successful nests were examined to determine the size of the hatch, the number of eggs remaining and the number of dead ducklings left in the box. The number of eggs hatched was determined by examination of the remains and counting the egg membranes which remain intact even though the shells are crushed.

Unsuccessful nests were examined to determine the reason for their failure and to ascertain the number of eggs lost, if any. Eggs left in the boxes were broken to determine if incubation had progressed enough to be apparent. Desertion was assumed where no eggs hatched and no definite evidence of interference was observed.

Other usage was recorded by species and the nature of usage. Some boxes might have been used for nesting or denning, some for roosting, while others might have been visited by an animal in search of prey.

All boxes with usage data completed were cleaned of egg remains, down and feathers to prevent confusion in the next year's data. New wood shavings were added where needed to maintain a level of about four inches in the box. Shavings were preferred over sawdust, since the sawdust tended to pack and become hard. A hard packed surface would not allow the eggs to be buried during the laying period and might have resulted in the female abandoning the box as a nest site.

WOOD DUCK HABITAT IN CALIFORNIA

Summer Habitat and Population

The greatest population of breeding wood ducks in the United States is found in the states from the upper Mississippi River eastward through New England. Ideal habitat, such as small wooded ponds, bogs, flooded swamps and slow moving streams, is interspersed throughout this area.

In California, the summer wood duck population is distributed sparsely over most of the state north of the Tehachapi Mountains. Their range includes a tremendous amount of marginal habitat. Much of this habitat consists of streams, rivers and reservoirs, ranging from the higher elevations to the river bottomlands in the valleys. Wood ducks were observed throughout this habitat wherever any effort was expended on box installation. There were 53 sites in the State where nest boxes were installed, and wood ducks utilized boxes in 46 of the sites.

There are, however, some areas of concentrations. These are located as follows: an area east of Anderson, Shasta County, which includes many wooded streams and the Sacramento River; Indian Valley in Plumas County; along the Feather River in Butte, Sutter and Yuba counties; the Butte Sink west of Gridley, Butte County; south along the western slope of the Sierras, including stretches of the Cosumnes, Mokelumne, Tuolumne, Merced, San Joaquin and Kings rivers. Most of the north coastal streams also are utilized by some breeding pairs. These areas mentioned are by no means a complete list of concentrations of breeding wood ducks in California. Other areas undoubtedly exist which were not located during the study.

Most of the available habitat in California is subjected to extreme fluctuations of water levels. This condition has a detrimental effect on most wildlife including the wood duck. Unstable water conditions may

play an important part in limiting the number of wood ducks breeding in the State. The major rainfall in California comes during the winter months and the flow in most streams is plentiful at that time. By late spring the runoff from the snow pack is under way, but much of this is diverted for agricultural purposes. The result is a decrease of water in streams until the flow in early summer is reduced to a minimum or stopped altogether. This decrease in available water coincides with the nesting season of the wood duck. The rapid decrease of water and the lack of natural nest cavities apparently are the important factors in making California habitat marginal. The fact that California is the southern extremity of the breeding range on the Pacific Coast also contributes to the limited breeding populations within the State.

As a result of field observations during the five-year study, the annual nesting wood duck population in California was estimated at 1,500 pairs.

The estimated breeding range of the wood duck in California is shown in Figure 10.

Winter Habitat and Population

California is the major wintering area for the wood duck on the Pacific Coast. A few stragglers are seen in Nevada and Arizona and some winter in Sinaloa, in Central Mexico (A.O.U. Checklist, 5th Edition).

There are more than 25,000 miles of streams and about 6,000 lakes and impoundments in California and many of those of lower elevation are utilized by wood ducks during the winter. Wood ducks have been recorded in the fall and winter from San Diego County, Imperial Valley, and Death Valley in the south to Humboldt and Siskiyou counties in the north. They have been reported in Santa Barbara, Ventura, and Mendocino counties on the coast and east to Yosemite National Park and Lake Tahoe in the Sierra Nevada Mountains. Central California, however, furnishes most of the winter habitat. Oak-covered foothills bordering the central valleys, the rice belt, and the river bottomlands are all adjacent to each other and, when combined with the warm winters and abundant rainfall, form an ideal winter habitat.

Although the wood duck is widely dispersed throughout the wintering range, there are areas of concentration. These areas correspond closely to the summer concentrations and may be found as follows: east of Anderson in Shasta County; in the vicinity of the confluence of Deer Creek and the Sacramento River in Tehama County; along the Feather River in Butte, Sutter and Yuba counties; the Butte Sink west of Gridley, Butte County; in the foothills of the Sierra Nevada Mountains, including the many rivers and streams draining into the central valleys as far south as the Kings River; and on the many reservoirs and streams along the Coast and Diablo ranges, south to Monterey County. The wood duck is rarely found along the sea coast or in the salt marshes.

The winter migration of the resident population in California amounts to a shift out of the higher elevations into the central valleys and adjoining foothills. The central valley is apparently the year-

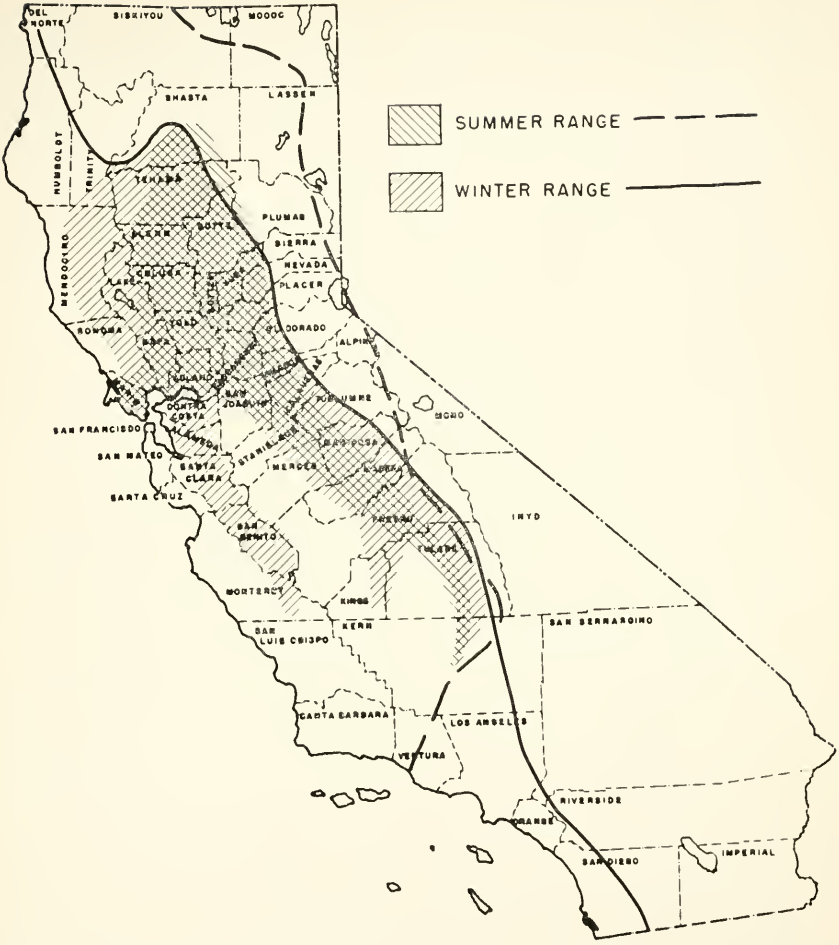

FIGURE 10. Estimated summer (breeding) and winter range of the wood duck in California. The shaded portions of the map indicate areas of higher densities of wood ducks. *(Drawn by Cliffa Corson.)*

round range of the wood ducks that breed there. The map in Figure 10 illustrates the estimated winter range in California.

Most of the wood ducks in the Pacific Flyway are produced in Washington, Oregon and California, with limited populations in western Montana, northern Idaho and the Columbia Basin in British Columbia. Recoveries of birds banded by those states indicate a fall migration into the wintering areas of California. The recovery pattern for banded wood ducks taken in California is shown in Figure 11. As seen from the map, the Coast Ranges north of San Francisco Bay, the Sacramento Valley and the northern San Joaquin Valley are important wintering areas on the Pacific Coast.

FIGURE 11. Migration of banded wood ducks into California. The large symbol indicates the banding station and the small symbol represents the area of return. *(Drawn by Cliffa Corson.)*

The extensive habitat in California, coupled with the secretive nature of the species, makes it very difficult to obtain an accurate census of the total population. In trying to resolve the question of how many wood ducks winter in the State, an indirect method was thought to be best. In this way, by determining the total fall population in those states where California's wintering wood ducks originate, the California pop-

ulation could be calculated. Table 1 presents the estimates by waterfowl technicians of the premigration populations within their states during 1958. It should be kept in mind that the wood duck does not lend itself to easy census and therefore the figures in the table are obtained under less than ideal conditions and may be subject to error.

TABLE 1

Fall Populations of Wood Ducks in the Pacific Flyway, 1958 [1]

Area	Estimated breeding pairs	Estimated total fall population[2]
British Columbia	200	1,000
Washington	[3]6,000	37,000
Western Montana	100	500
Northern Idaho	560	3,300
Oregon	[4]7,500	35,000
California	1,500	7,200
Total	15,860	84,000

[1] Arizona and Nevada are not included.
[2] Where only pairs were given, the total fall population was computed with average figures of 70 percent nesting success and four young per brood fledged.
[3] Number of breeding pairs not given, but an estimated 33 percent were adults.
[4] Nesting success at 66 percent, or 5,000 successful pairs, and 4 young per brood fledged.

As shown in Table 1, approximately 84,000 wood ducks were present in the flyway at the beginning of the 1958 hunting season. The estimated number of wood ducks killed in the Pacific Flyway during the 1958-59 waterfowl season was over 22,400 birds (Crissey, 1959). This estimated kill subtracted from the total flyway population left a post hunting season population of about 61,600 wood ducks in the flyway. It was estimated that at least 90 percent of the flyway population, or about 55,400 wood ducks, wintered in California. The above data are admittedly rough and unrefined but they do give a better picture of the wood duck's status in California as it exists at the present.

There is a definite need for a reliable method of censusing wood ducks, both in the summer and winter. One of the objectives of this study was to devise a census method in California, but very little information was obtained.

Various census methods, including aerial surveys, stream surveys, and brood counts have been tried by other states, with varying degrees of success. One of the latest methods, now being tried in other states, is an evening count at known roosting locations. This method appears to hold some promise for more efficiency in measuring the trend of wood duck populations. A report on wood duck research methods (Massachusetts Division of Fisheries and Game, undated) states: "An overall census of waterfowl populations, however, may be open to wide misinterpretation since the degree to which any individual species can be censused may vary greatly. Wood ducks in particular are difficult to census at this season. Often the woodies form in bands which frequent areas different from those occupied during the summer months. Usually these areas are swamps, wooded streams, and small areas difficult to census by ordinary methods. Perhaps the best census of wood ducks at this season can be obtained by evening flights at known concentration

points. In view of the many varying influences which must effect the censusing of a wood duck population it would seem that more information can be gathered from intensive study on a few areas than by an extensive but superficial count on many areas. This is evident at least until such time as census techniques proved by intensive study can be developed and applied on an extensive basis."

LOCATION OF NEST BOXES

The nest box program was started in California in 1952 on a very limited scale, with only eleven boxes being erected during the year. The project was expanded to 47 boxes during 1953 and to 145 boxes in 1954. The number of boxes available fluctuated considerably each year, due to loss by destruction and to the relocation of some boxes on better sites. Attention was given primarily to a waterway or an area considered to be good habitat. The region and county in which it was located was of little significance. The number of boxes in the various counties is shown in Table 2.

TABLE 2

Location and Number of Wood Duck Nest Boxes Installed 1952-1956

Region	County	Number	Region	County	Number	Region	County	Number
I	Shasta	13	II	Plumas	19	III	Lake	6
	Humboldt	12		Yuba	16		Marin	5
	Modoc	4		Colusa	11		Mendocino	2
	Lassen	3		Sacramento	6			
	Tehama	3		Sutter	5		Total	13
				Yolo	5			
				Butte	4	IV	Merced	23
							Fresno	15
	Total	35		Total	66		Total	38

All Regions grand total 152

As illustrated in Figure 12, most of the major river drainages were sampled. For the most part, wood duck habitat in California is associated with the streams and rivers. Small permanent ponds and bogs do not exist in any number. Where small ponds and water areas did exist, an effort was made to erect boxes on those sites. More work should have been done on the many dredger ponds along the western slope of the Sierra Nevada Mountains. The number of boxes installed and the areas covered were considered sufficient to permit an evaluation of the program.

NEST BOX UTILIZATION

Wood Duck Usage

Percent of Boxes Used

It may be determined from Table 3 that an average of 42 percent of the boxes were used by wood ducks. Usage of the boxes by other wildlife was recorded in 31 percent of the functional boxes. There was no activity recorded in 31 percent of the boxes.

FIGURE 12. Wood duck nest box sites in California. Each dot indicates one or more nest boxes installed in the area. *(Drawn by Cliffa Corson.)*

The degree of usage by wood ducks varied greatly throughout the different areas in the State. The boxes filled a vital need in areas where natural cavities were lacking, while in other areas of equal appearance only limited use occurred. In areas of limited nest box use, it was assumed that the number of natural cavities was sufficient, that there was a small population of wood ducks present, or that some other factors influenced the nesting. Figure 13 illustrates typical wood duck usage.

Nesting Period

The beginning of the nesting season in California depended upon the particular area under consideration. The nesting cycle usually began earlier in the southern part of the range and was progressively later

TABLE 3

Nest Box Utilization

	1952		1953		1954		1955		1956		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Boxes missing	--	--	--	--	--	--	9	6	--	--	9	2
Boxes not checked	--	--	--	--	7	5	7	5	14	10	28	6
Boxes nonfunctional	1	9	1	2	12	8	14	10	25	19	53	11
Boxes functional*	10	91	46	98	126	87	111	79	95	71	388	81
Total boxes installed	11	100	47	100	145	100	141	100	134	100	478	100
Boxes used by wood ducks†	4	40	18	39	38	30	50	45	54	57	164	42
Boxes used by other wildlife	4	40	18	39	37	29	34	31	26	27	119	31
Boxes unused	3	30	12	26	55	44	31	28	21	22	122	31
Total	11	110	48	104	130	103	115	104	101	106	405	104

* The numbers listed after "Boxes functional" were used to compute the percentage in the lower half of the table.
† Includes 17 boxes that had double usage; this explains the totals over 100 percent.

FIGURE 13. A nest box used by a wood duck. Note the abundance of down which is typical of wood duck nests.

TABLE 4

Fate of Nests in Wood Duck Boxes

Fate	1952		1953		1954		1955		1956		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Successful nests	2	50	11	61	31	82	42	84	39	72	125	76
Destroyed nests	0	0	3	17	5	13	2	4	3	6	13	8
Deserted nests	1	25	2	11	2	5	4	8	7	13	16	10
Dump nests	1	25	2	11	0	0	2	4	5	9	10	6
Total nests	4	100	18	100	38	100	50	100	54	100	164	100

to the north. Average dates taken from known nesting periods in wood duck boxes indicated egg laying started about the last week of March in the San Joaquin Valley and during the second week of April in Plumas and Humboldt counties. In general, the nesting season was usually in progress throughout the State after the middle of April. Nesting activity progressed at a more liesurely pace in the southern portion of the range. Most of the nesting activity was completed by July 15 except for an occasional late nest or a renesting attempt.

Nesting Success

A nest was considered successful if one or more ducklings were known to have departed from the box. Only in one instance did all young fail to leave the box after hatching. In every successful nest, the characteristic egg membranes and caps were found in the box. The presence of these remains was the criteria used in determining the fate of the nest.

During the five-year period, nest history data were recorded on 164 wood duck nests. Of these, 125 nests (76 percent) were successfully hatched, 16 (10 percent) were deserted, 13 (8 percent) were destroyed and 10 (6 percent) were recorded as dump nests. Table 4 summarizes all data gathered of the fate of nests throughout the study.

Clutch Size

Clutch sizes ranged from a nest containing one egg to a dump nest of 43 eggs. Successful clutch sizes ranged from 3 eggs to 28 eggs and the average, based on 125 successful nests, was 13.3 eggs per nest (Figure 14). However, this average clutch size was considered to be biased by the influence of parasitism of nests by other females. Nests containing 10 to 14 eggs made up 52 percent of the successful nests and represented those nests in which a minimum of parasitism had occurred. The average clutch size of this group of nests was 11.8 eggs and was considered to be a more valid figure for wood ducks.

A dump nest was defined as the product of more than one female and no attempt was made to incubate the eggs. A total of 10 dump nests were recorded during the study which contained 285 eggs. The average clutch size for dump nests was 28.5 eggs per nest. The dump nests and large clutch sizes of successful nests indicated that there was considerable competition among the females for nesting sites. Additional boxes installed in the areas of competition would have helped to alleviate this condition.

Hatching Success and Production

Successful nests contained a total of 1,663 eggs, of which 1,295 or 78 percent hatched. The young experienced little difficulty in leaving the boxes after hatching. A total of 1,253 (97 percent) ducklings scrambled out of the boxes during the study. Data obtained on nest box utilization by wood ducks is summarized in Table 5.

Unsuccessful Nests

Unsuccessful nests were recorded as deserted or destroyed. Dump nests were included in this category for lack of a better place. A total of 39 nests (24 percent) were classified as unsuccessful during the study.

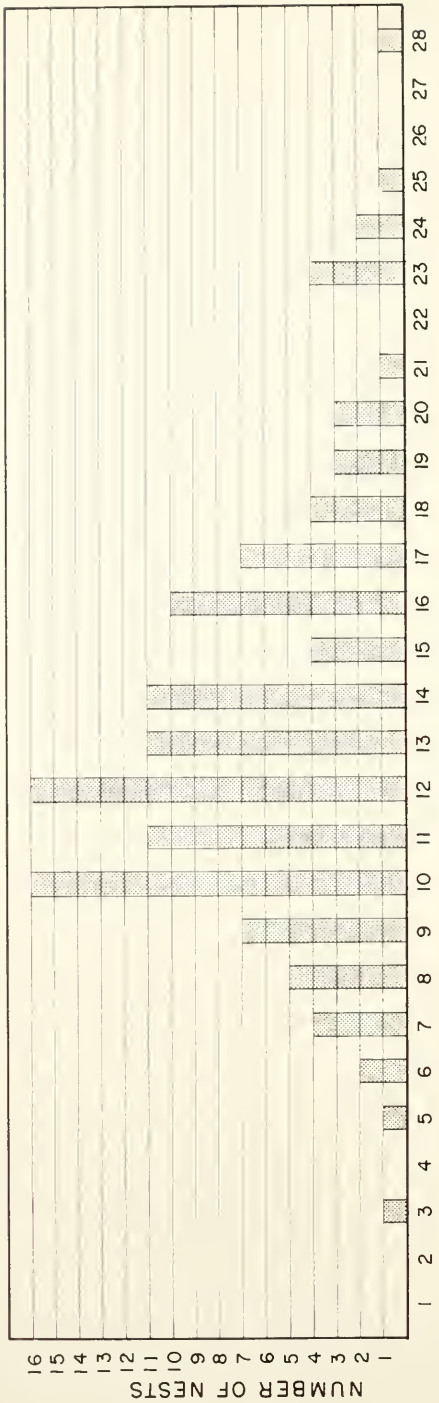

FIGURE 14. Number and size of successful clutches recorded during the nest box study. *(Drawn by Cliffa Carson.)*

TABLE 5

Summary of Wood Duck Nest Box Data

	1952	1953	1954	1955	1956	Total
Total wood duck nests	4	18	38	50	54	164
Total eggs, all nests	61	265	483	644	764	2,217
Average clutch, all nests	15.3	14.7	12.7	12.9	14.1	13.5
Successful nests	2	11	31	42	39	125
Total eggs, successful nests	24	154	438	516	531	1,663
Average clutch, successful nests	12.0	14.0	14.1	12.3	13.6	13.3
Total eggs hatched	24	122	344	438	367	1,295
Average hatch in successful nests	12	11.1	11.1	10.0	9.0	10.4
Total young produced	24	122	344	438	367	1,295
Total young leaving boxes	24	118	335	422	354	1,253
Average young leaving each box	12	10.7	10.8	10.0	9.0	10.0
Percent of young leaving boxes	100	97	97	96	96	97

Desertion was recorded in 16 (10 percent) nests. Desertion was assumed where no definite evidence of interference was observed. The causes of desertion are very difficult to determine. Competition among females for nesting sites, human interference and competition with other species of wildlife for use of boxes were considered to be causes of desertion.

There were 13 nests (8 percent) destroyed. The main factor causing nest destruction was attributed to human molestation. Human molestation accounted for a total of eight nests that were broken up by the removal of eggs or destruction of boxes containing nests. Raccoon predation, which is prevalent in nest box programs in eastern states, was found in only two boxes and suspected in two more during this study.

Six percent (10 nests) of the boxes used by wood ducks contained dump nests.

Other Usage

In addition to usage by wood ducks, the boxes provide nesting and resting sites for many other species of wildlife. The other species were considered a nuisance as far as the wood duck nest box program was concerned. A total of 119 boxes (31 percent) was occupied by 12 species other than wood ducks. Those most commonly found using the boxes were sparrow hawks, honey bees and screech owls. Table 6 presents a list of wildlife, other than wood ducks, utilizing the boxes during the study.

Nonfunctional Boxes

A box was considered nonfunctional when there was a condition present to impede usage. Such conditions included tops missing from boxes, absence of shavings in box, large splits in box sides, box concealed by vegetation, boxes which had fallen down, boxes flooded by high water, and some types of human molestation such as shooting boxes.

A total of 450 boxes was checked during the study and 51 (11 percent) were found to be nonfunctional. As the boxes became older the

TABLE 6

Number of Boxes Used by Other Wildlife

Species	Number of boxes	Percent
Sparrow hawk	27	22
Honey bees	23	19
Screech owl	21	18
Red-shafted flicker	11	9
Ringtailed cat	8	7
Tree swallow	8	7
Brown rat	6	5
Barn owl	5	4
Bird (unknown)	4	3
Wren	3	3
English sparrow	2	2
Mammal (unknown)	1	1
Total	119	100

number that were nonfunctional increased proportionately (Figure 15). As a result of flood conditions throughout California during the winter of 1955-56, the number of nonfunctional boxes nearly doubled. Many of the trees containing nest boxes were knocked down by the flooding streams and rivers.

MAINTENANCE

The number of boxes successfully used by wood ducks each year ultimately determines the value of the program. Such a program cannot rest with the initial installation of the boxes but must have maintenance that is both adequate and continuing. In a successful program, boxes must be in a condition acceptable to the birds at the beginning of each nesting season.

It was found that soundly constructed boxes of good lumber resisted deterioration for long periods. However, when wooden boxes are used, maintenance and upkeep become a part of the program. Boxes that were destroyed by flooding, vandalism and irreparable splitting had to be replaced. The replacement of destroyed boxes was carried out at the time of the nesting checks during the summer. Nonfunctional boxes were repaired when found. The major cause of nonfunctional boxes was the occurrence of large splits in the sides below the entrance hole. In most cases, such boxes were not accepted by female wood ducks as nesting sites. Black weather stripping cement was squeezed into the split, which was then closed with a few corrugated fasteners. This method proved to be successful and little time was required to repair a box in this manner.

Extra lids were carried at all times and were used as replacements where needed. Shavings were often removed from a box by other wildlife and it became standard procedure to have extra shavings along when checking the boxes for usage. In some areas, especially the north coast, the boxes were concealed by rapid vegetative growth after their installation. This new cover needed chopping away each year (Figure 16).

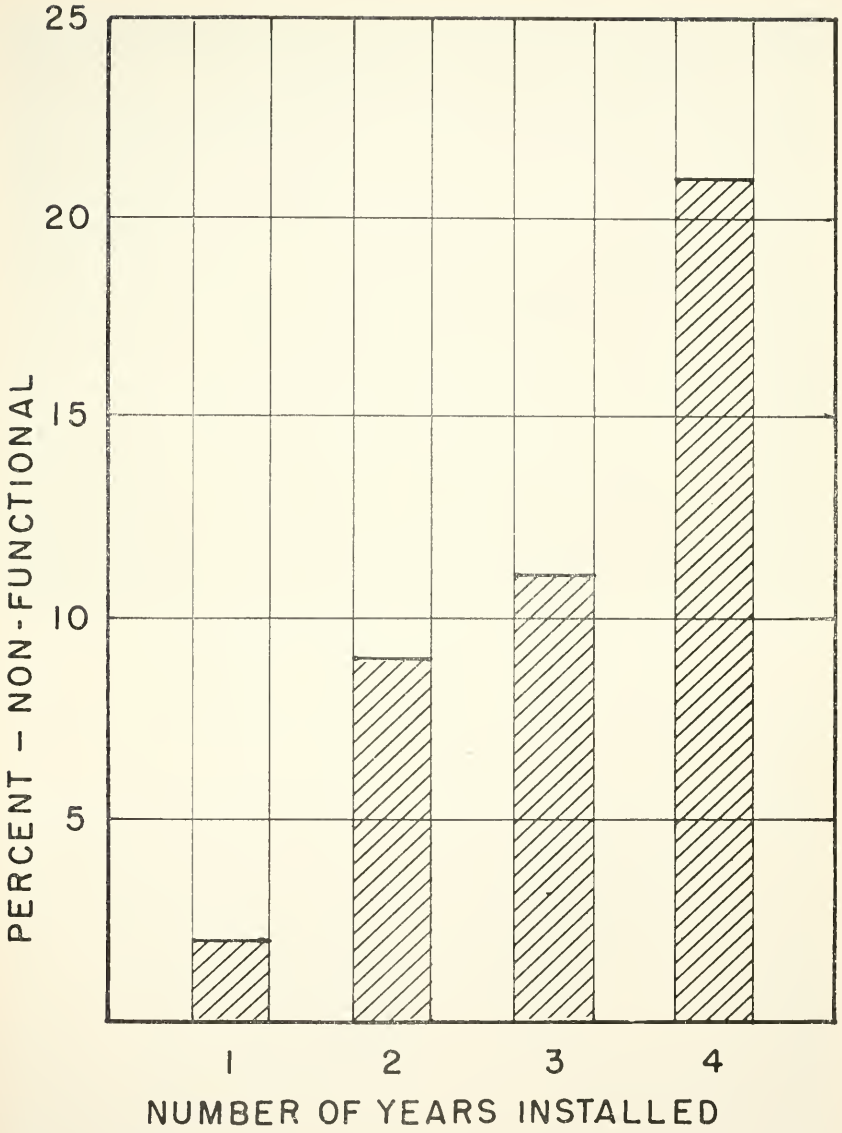

FIGURE 15. The percentage of nonfunctional boxes in relationship to the length of time that the boxes were installed. *(Drawn by Cliffa Corsan.)*

During the early part of the study, considerable trouble was caused by honey bees. They took over nest boxes and used them as hives. The boxes containing bee hives were poisoned with cyanide during the winter when the colony of bees was dormant. The boxes were then

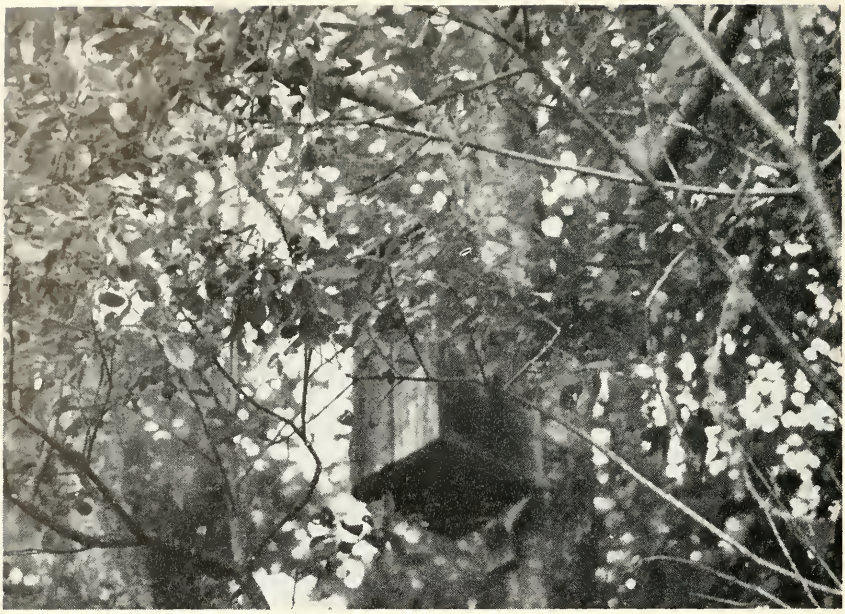

FIGURE 16. This box in Humboldt County was concealed by vegetative growth and was considered nonfunctional.

cleaned out and replaced. Some experimenting was done with repellents and the following three types were used with success:

1. Four ounces of chlordane added to one gallon of black creosote.
2. One ounce of chlordane to one quart of motor oil.
3. Fifty percent wettable DDT mixed to a paste with water.

The honey bees attached their comb to the lid of the box, as shown in Figure 17, so only the lid of a box was treated with repellents. The lids of all boxes were treated during the first check of each year after 1953. Honey bee usage was reduced to a minimum after the repellents were used. During the 1953 nesting season 35 percent of the boxes were occupied by honey bees. After a winter application of repellents less than two percent of the boxes contained bees in the 1954 nesting season.

Female wood ducks showed no aversion to occupying a treated box; nest abandonment due to the repellents never occurred.

The use of repellents will be a necessity in nest box programs in the Sacramento and San Joaquin Valleys where the majority of the bee usage occurred.

Some states now have gone into programs using metal boxes. These boxes are cylindrical in shape and are constructed of galvanized, sheet metal, cold air pipe. They were designed to reduce nest predation and to increase the durability. Although metal boxes were not used in this study, they should be considered in any future programs.

FIGURE 17. The lid of a nest box with attached honey comb. The lids were treated with repellent to minimize this usage.

CONCLUSIONS

It was concluded that nest boxes could have a definite bearing on the number of wood ducks produced in California each year. A coordinated program could be integrated into the unit management system used by the California Department of Fish and Game with little conflict of present duties. Unit managers could guide the efforts of boy scout groups and sportsmen clubs interested in enhancing the habitat of wood ducks. The installation of boxes could be accomplished during slack work periods and the checking of success carried in a short period during the spring.

If a sufficient number of boxes could be installed, breeding population trends could be correlated with the wood duck usage in the nest boxes.

SUMMARY

1. Information is presented on the early history and abundance of the wood duck in California. Destruction of habitat and overshooting caused the early decline in numbers of wood ducks. Hunting restrictions have resulted in a partial recovery of the species.

2. The summer range extends over much of California north of the Tehachapi Mountains. The breeding population was estimated at 1,500 pairs. California is the major wintering area for wood ducks on the Pacific Coast. Central California furnishes habitat for most of the estimated wintering population of about 55,400 wood ducks.

3. A five year study, 1952-56, was conducted to determine the feasibility of a nest box program.

A total of 152 boxes was installed and 42 percent were used annually by wood ducks.

Seventy-six percent of the nests hatched successfully. The average clutch size of successful nests was 13.3 eggs. Dump nests averaged 28.5 eggs per nest.

Desertion was recorded in 16 percent of the nests; destruction occurred in eight percent of the nests.

4. A total of 119 boxes (31 percent) was occupied by species other than wood ducks. Sparrow hawks, honey bees and screech owls were most commonly found using the boxes.

5. An average of 11 percent of the boxes was found to be nonfunctional each year.

6. Adequate maintenance must be included in any program of nesting box installation.

ACKNOWLEDGMENTS

The success of the nest box study was due largely to the efforts of many employees of all branches of the California Department of Fish and Game. All personnel of Federal Aid in Wildlife Restoration, Project W30R, assisted throughout the study. Richard Robinson of Fresno State College located many of the nest box sites and recorded information on the wood duck in the San Joaquin Valley. Humboldt State College students assisted with construction and installation of the boxes in Humboldt County. Appreciation is due to the members of the Pacific Flyway Technical Committee and especially Chester Kebbe of Oregon, Robert Salter of Idaho, Robert Jeffery of

Washington, Ron Mackay of British Columbia, and Dwight Stockstad of Montana, who compiled population data for their respective states. Special thanks are given to the landowners throughout the State who permitted unrestricted access to their land during the study.

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USE OF DESERT SHRUBS BY JACKRABBITS IN NORTHEASTERN CALIFORNIA[1]

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INTRODUCTION

Observations by the authors while doing field work indicated that the jackrabbit *(Lepus californicus)* approached or reached a peak in population density in 1958-59 in northeastern California. These observations were substantiated by the number of requests received by the Lassen County Agricultural Commissioner for poison for jackrabbits. Requests reached a maximum number in 1958-59 and decreased in 1959-60. Furthermore, those ranchers who requested poison in 1959-60, reported that jackrabbits were much less abundant than they were the previous year.

Particularly heavy concentrations of rabbits were noted on certain areas, and desert shrubs on these areas were used intensively for food by the rabbits. To determine the degree and type of use being made of the various species of shrubs, a study was made at Turtle Point, near Herlong, Lassen County, California. The area lies at the western edge of the Great Basin and immediately east of the Sierra Nevada escarpment.

STUDY METHODS AND DESCRIPTION OF VEGETATION

A transect of sixteen 1/20-acre plots was located at right angles to an east facing slope, extending from an elevation of 4,120 feet down to 4,065 feet (Figure 1). A random starting point was chosen and plots were taken at two-chain intervals along a predetermined bearing.

Jackrabbit use consisted of browsing and girdling. Browsing was tabulated as light (trace browsing), moderate (up to ¼ of main branches browsed), and heavy (¼ or more of main branches browsed). Girdling was tabulated as the percentage, to the nearest 10 percent, of main live stems showing some degree of girdling. The degree of both types of use for a given plant was based upon a subjective estimate by the senior author.

Vegetation on the area was composed principally of eight species of shrubs. At the highest elevation, desert peach *(Prunus andersonii)* was the predominant species, with some big sagebrush *(Artimisia tridentata)* and bitterbrush *(Purshia tridentata)* present. As the elevation

[1] Submitted for publication January, 1960.

FIGURE 1. View of area where study was made. That portion of the area immediately beyond the shrub type was covered with a pure stand of winterfat. August, 1959.

decreased, composition of the vegetation changed; at the lowest elevation was a pure stand of four-winged saltbush *(Atriplex canescens)* (Table 1). Beyond the saltbush, but not included in the transect, was a pure stand of winterfat *(Eurotia lanata)*.

RESULTS AND DISCUSSION

Girdling was confined principally to hopsage *(Grayia spinosa)*, desert peach, and horsebrush *(Tetradymia glabrata)* (Figure 2). Hopsage showed heaviest use with 79 percent of the plants showing some girdling, and all the main stems girdled on 51 percent of the plants (Figure 3). Desert peach showed some girdling on 72 percent of the plants, and 17 percent had some use on all the main stems.

All of the large main stems on many plants had been killed by girdling, and new sprouts had developed from the roots. Only 16 percent of the horsebrush had any girdling.

Minor girdling was found on three other species. One bitterbrush plant showed less than 10 percent use, two rabbitbrush plants *(Chrysothamnus nauseosus)* showed 10 and 20 percent use, and one four-winged saltbush showed 50 percent use.

All of the eight principal species of shrubs showed some browsing (Figure 4). Four-winged saltbush and hopsage had some browsing on all plants, with 79 and 70 percent, respectively, in the heavily browsed

TABLE 1

Composition of the Desert Shrub Type at Turtle Point, Near Herlong, California. (Plot 1 had an elevation of 4,120 feet; plot 16 had an elevation of 4,065 feet; plots 2-15 were intermediate.)

Plot number	*Tetradymia glabrata*	*Grayia spinosa*	*Purshia tridentata*	*Prunus andersonii*	*Artemisia tridentata*	*Chrysothamnus nauseosus*	*Chrysothamnus viscidiflorus*	*Atriplex confertifolia*	*Aphedra* sp.	*Eurotia lanata*	Total by plots
	Number of plants										
1[1]											
1	0	0	19	112	8	1	1	0	2	0	143
2	18	0	0	13	1	7	2	0	0	0	41
3	26	0	10	6	3	14	0	0	0	0	59
4	30	2	2	8	3	24	2	0	0	0	71
5	7	3	3	1	14	26	0	0	1	0	55
6	20	10	0	4	35	1	11	0	0	0	81
7	15	1	0	3	18	0	16	0	0	0	53
8	36	9	0	19	18	0	16	0	0	0	98
9	59	12	0	0	9	0	1	1	0	0	91
10	17	17	0	4	7	1	48	1	0	0	95
11	25	1	0	32	37	4	6	0	0	0	105
12	28	0	0	2	37	0	2	0	0	0	69
13	34	2	0	0	12	0	4	13	0	0	65
14	3	0	0	0	0	33	15	8	0	0	59
15	0	0	0	0	5	1	8	29	0	1	44
16	0	0	0	0	0	0	0	20	0	0	20
Species totals	318	57	34	213	207	112	132	72	3	1	1,149

[1] Plot 1 was 1/10 acre; all others were 1/20 acre.

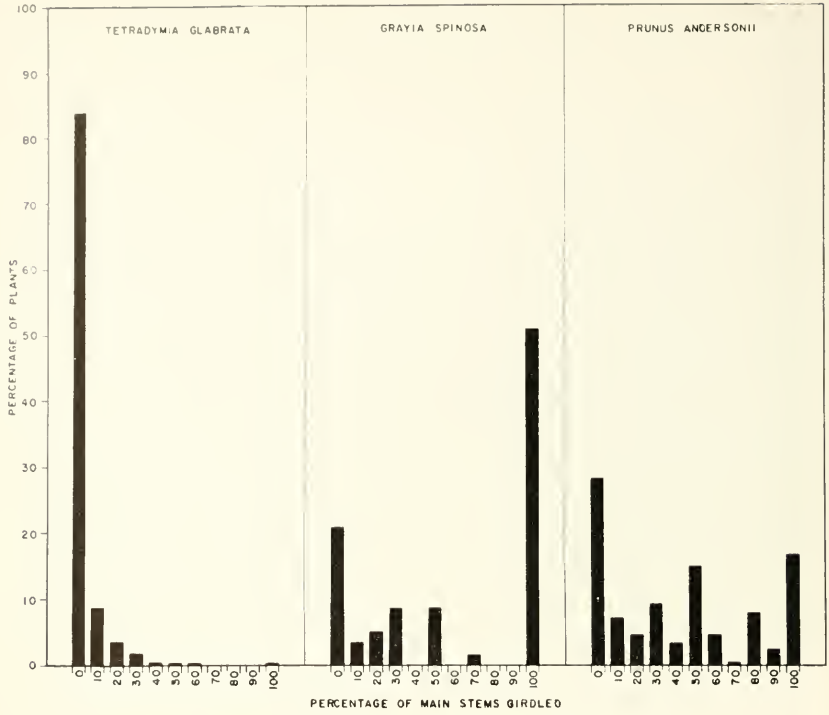

FIGURE 2. Degree of girdling of desert shrubs by jackrabbits near Herlong, Lassen County, California.

class (Figures 5 and 6). Seventy-six percent of the bitterbrush were browsed, but none fell in the heavily browsed class. Desert peach showed some use on 72 percent of the plants, with 30 percent heavily browsed. Sixty percent of the big sagebrush were browsed, and 26 percent showed heavy use.

Only minor browsing was found on the other three principal species. Thirty percent of the horsebrush plants showed use, but only 2 percent were in the heavy class. *Chrysothamnus nauseosus* showed some browsing on 34 percent of the plants, with 12 percent in the heavy class. Twelve percent of the *C. viscidiflorus* plants had been used and three percent were in the heavy use class.

No tabulation was made of browsing of winterfat, but it was estimated that over 90 percent of the plants near the shrub type showed some use. In this type, as in the shrub type, rabbit pellets were very abundant (Figure 7). Use of winterfat diminished as the distance from the shrub type increased, probably because winterfat does not provide adequate cover.

It is conceivable that the composition of the desert shrub type could be altered by jackrabbit use of the intensity described here. Browsing and girdling of hopsage and repeated girdling of desert peach could result in partial elimination of these two species. Heavy browsing of

FIGURE 3. Girdling of hopsage by jackrabbits. July, 1959.

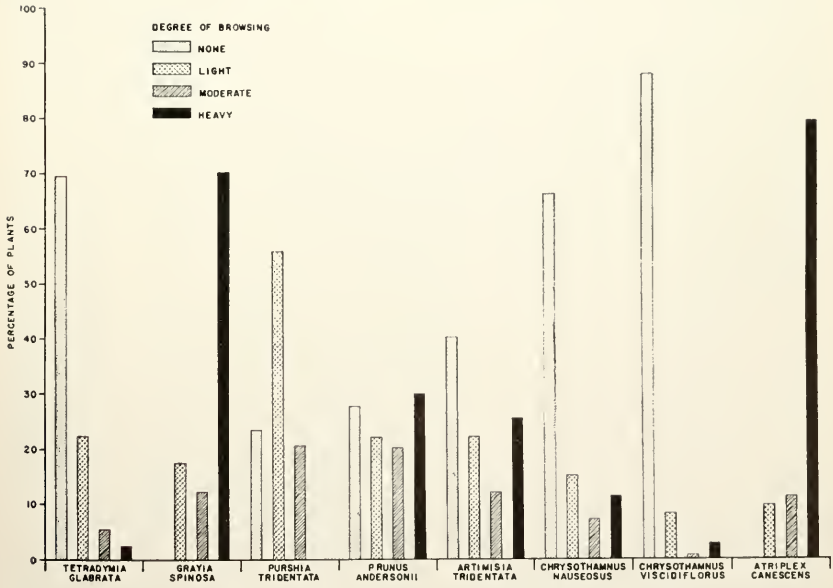

FIGURE. 4. Degree of browsing of desert shrubs by jackrabbits near Herlong, Lassen County, California.

FIGURE 5. Four-winged saltbush showing extremely heavy browsing by jackrabbits. July, 1959.

FIGURE 6. Hopsage which has been heavily browsed by jackrabbits. July, 1959.

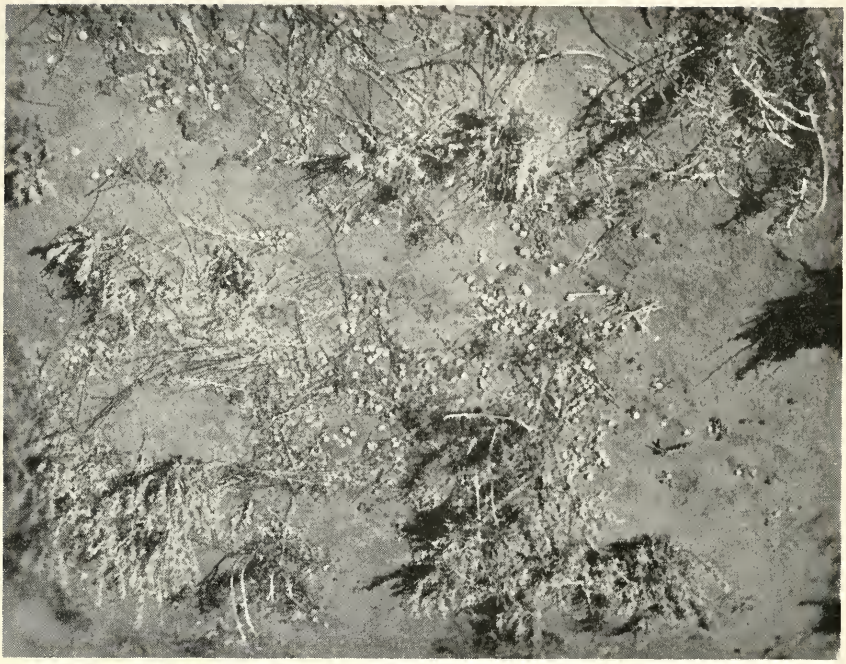

FIGURE 7. Winterfat which has been heavily browsed by jackrabbits. Note the clipped but uneaten items on the ground and the heavy concentration of rabbit pellets. August, 1959.

four-winged saltbush could result in suppression of this species. The other species probably would be little affected once established, but a high population of jackrabbits could prevent survival of seedlings.

SUMMARY

High densities of jackrabbits were observed in northeastern California in 1958-59, and on some areas desert shrubs were used intensively for food by the rabbits. A study was made to determine the degree and type of use.

Girdling occurred principally on hopsage, desert peach, and horsebrush; the degree of use was 79, 72, and 16 percent, respectively. All main stems were girdled on 51 percent of the hopsage plants.

All of the principal shrub species exhibited some browsing. Four-winged saltbush and hopsage were the species most used; all plants were browsed to some degree, and 79 and 70 percent, respectively, were heavily used. Seventy-six percent of the bitterbrush, 72 percent of the desert peach and 60 percent of the big sagebrush were browsed, but heavy browsing occurred on no bitterbrush, on 30 percent of desert peach, and on 26 percent of big sagebrush. Less than 30 percent of the horsebrush and rabbitbrush were browsed.

Use of desert shrubs for food by jackrabbits, at the rate observed during this study, could result in a change in composition of the type. Hopsage, desert peach and four-winged saltbush would be the species most likely to be eliminated or suppressed.

THE AGE AND GROWTH OF STRIPED BASS *(Roccus Saxatilis)* IN CALIFORNIA[1]

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INTRODUCTION

By far the most important population of striped bass in California is centered in the San Francisco Bay area and the lower reaches of the Sacramento-San Joaquin river system.

Over the years, angling pressure on this population has increased markedly, and many changes have occurred in the environment of this popular game fish. An understanding of the effects of these factors on the population is highly desirable for management purposes. A thorough knowledge of the life history of the fish is essential in achieving such understanding, and age and growth characteristics form an important phase of life history.

The only previous extensive growth study of this population was made by Scofield (1931). Length-weight-age relationships were determined by Clark (1938), using Scofield's age material. The present angling regulation fixing the minimum length limit at 16 inches is based on this early work.

Since the changes in fishing pressure and the environment that have occurred during the intervening years could have affected the growth rate, and in the light of the previously stated considerations, another age and growth study was initiated during the fall of 1957.

METHODS AND MATERIALS

A total of 1,089 scale samples was collected from striped bass caught by angling in San Pablo Bay and the lower Sacramento-San Joaquin Delta area during the fall of 1957 and summer and fall of 1958. Several scales were taken from the left side of each fish in the area above the lateral line and below the origin of the second dorsal fin. Key scales were not used. Fork length, weight, and sex were recorded for each fish. The sex was determined by examination of the gonads.

In the laboratory, three scales that were not torn or regenerated were selected from each sample. These were cleaned and impressed on 1 x 3 x 0.030-inch cellulose acetate slides. Scales from 138 fish were unusable, leaving 951 for the study.

An Eberbach scale projector with a 32mm. Macro Tessar lens providing a magnification of 42x was used to age and measure the scales. They were aged by counting annuli, which Scofield had shown to be valid. The locations of the focus, the annuli, and the scale margin for

[1] Submitted for publication February, 1960. This work was performed as part of Dingell-Johnson Project California F-9-R, "A Study of Sturgeon and Striped Bass," Supported by Federal Aid to Fish Restoration funds.

each scale [2] were marked on a paper strip for later use in determining the body length-scale length relationship and in back calculating growth. All scales were aged independently by two men, and the few scales on which they could not agree were rejected for growth calculations.

The radius of each scale was measured to the nearest millimeter, and averaged for the three scales from each fish. The fish were then grouped by scale radius intervals of one centimeter and the mean body length for each group was found using the method of Whitney and Carlander (1956). The body length-scale length relationship was then determined by plotting the mean fork length of the fish in each scale measurement group against the scale length and fitting a regression line to the data.

The back calculation of growth was accomplished using a direct proportion nomograph corrected for the Y axis intercept.

The length-weight relationship was determined by grouping the fish by one-inch body length intervals and computing the mean fork length and weight of the fish in each interval. These averages were then converted into logarithms and the linear regression was used following the method described by Sigler (1953).

[2] All scale measurements were made along the radius from the focus to the center anterior edge.

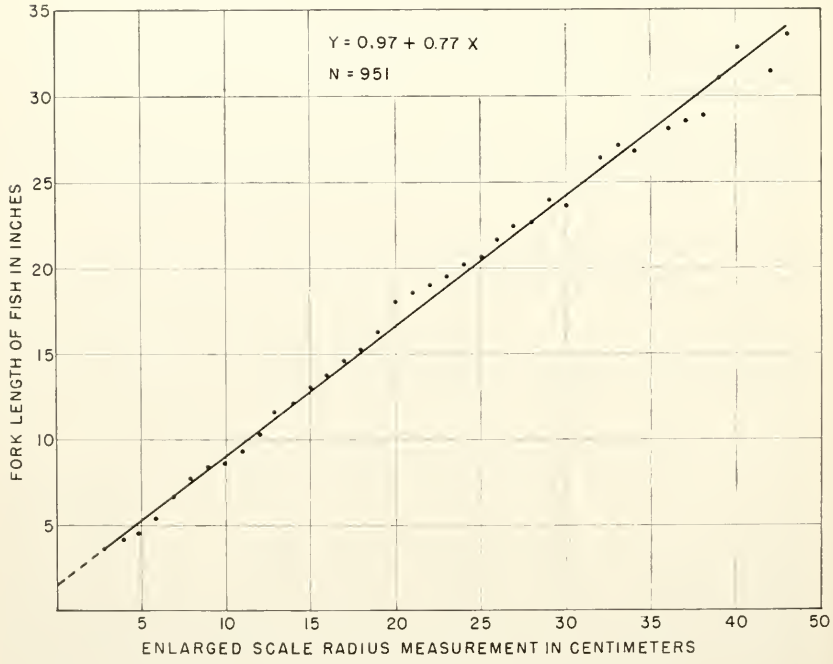

FIGURE 1. Striped bass body length-scale length relationship.

RESULTS

Body Length-Scale Length Relationship

The relationship between body length and scale length is shown in Figure 1. A straight line fitted to the points by the least squares method is described by the formula $Y = 0.97 + 0.77X$, where Y is the fork length of a fish in inches, X is the enlarged scale radius measurement in centimeters, and 0.97 is the Y axis intercept of the regression line in inches. Since the smallest fish sampled were three inches long, the Y intercept is an artificial value significant only for back calculating growth and is not necessarily the body length at time of scale formation. The linear relationship between scale length and body length indicates that scale length and body length of striped bass increase proportionately at least from 3 inches to 34 inches. Scofield (1931) and Merriman (1941) also found a proportional relationship within the size ranges they studied.

Growth

The growth histories of all fish of ages II through IX were calculated. Age I fish were not used because of the difficulty encountered in determining sex. The mean length at the end of each year of life was calculated separately for each fish, and these lengths were aver-

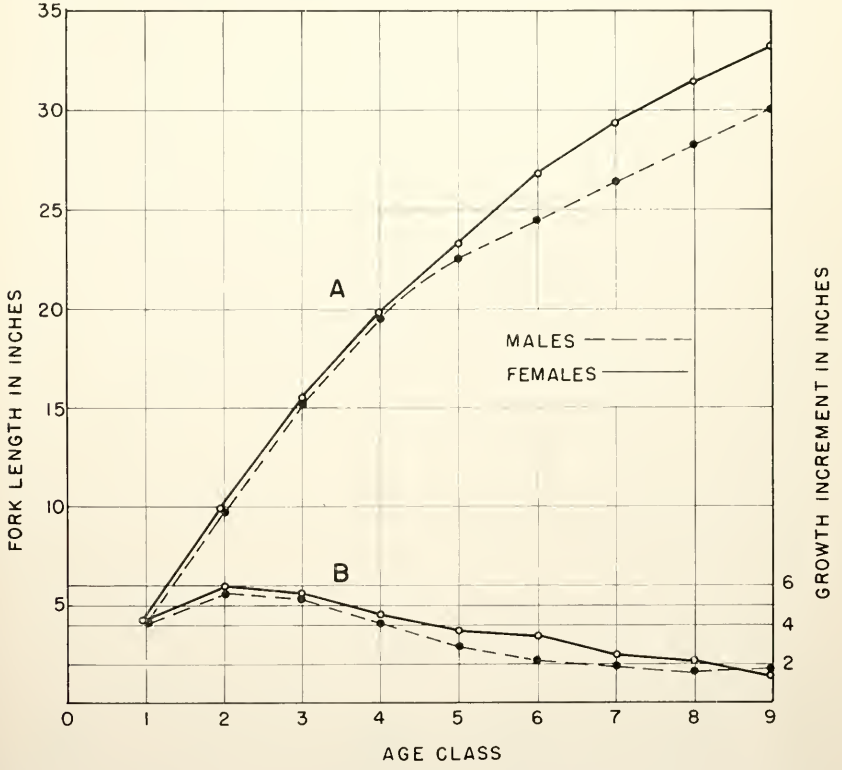

FIGURE 2. Growth of striped bass as calculated from scales. Upper lines (A) show rate of growth. Lower lines (B) indicate annual growth increment.

aged to get a mean length at the end of each year of life for each age group for each sex (Tables 1 and 2). The means for each year of life were then averaged by sexes to get the weighted grand average calculated length. The average annual increments of growth were then determined for each year of life (Tables 1 and 2).

These data indicate that male and female striped bass grow at the same rate for the first three years of life. Subsequently, females grow faster. The greatest difference in annual growth was reached at ages VII and VIII, when it was 3.0 inches and 3.3 inches, respectively (Figure 2). (Age VIII is based on a sample of only five fish, so little reliance can be placed in the calculated difference at that age.) The greatest annual growth of both males and females, 5.7 inches, occurred in the second year of life (Tables 3 and 4, Figure 2).

The validity of back calculating growth is confirmed by the similarity between measured lengths at capture and calculated lengths for fish of the same age groups (Table 5). Most of the fish were collected in the fall, after most of their year's growth was completed, but before the annulus was formed. Therefore, measured lengths were compared with calculated lengths of fish a year older.

The discrepancy between the third year growth increments found by the two methods was caused by biased sampling of age I+ and II+ fish. Age I fish were collected in August, before their annual growth was completed. Moreover, most age II fish were from the upper half of

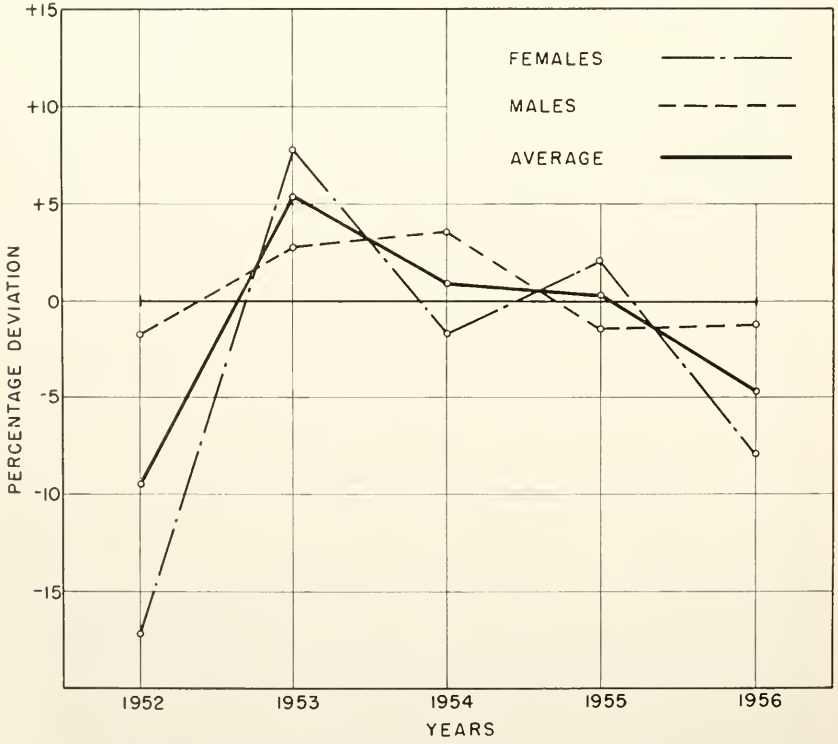

FIGURE 3. Percentage deviation from the mean annual growth increment of striped bass.

the length distribution, since fish in the lower half of the length distribution were protected by the 16-inch minimum size limit when these samples were taken.

Annual Fluctuations in Growth Rate

To determine annual fluctuations in the growth, the percentage deviations from the mean annual increment were calculated according to the method described by Hile (1941), using the mean annual increments in Tables 1 and 2. All age groups were weighted equally. The period 1949 to 1951 was eliminated from the calculations because the age groups VII, VIII, and IX are poorly represented.

The percentage deviations for the 1952 to 1956 period are shown in Table 6 and Figure 3. Growth was slow in 1952, and faster than average the next three years, with the maximum for the period occurring in 1953. From 1953 to 1956 there was a steady decline in growth.

These data show that there are annual fluctuations in growth. However, so few years of data are involved that the significance of the

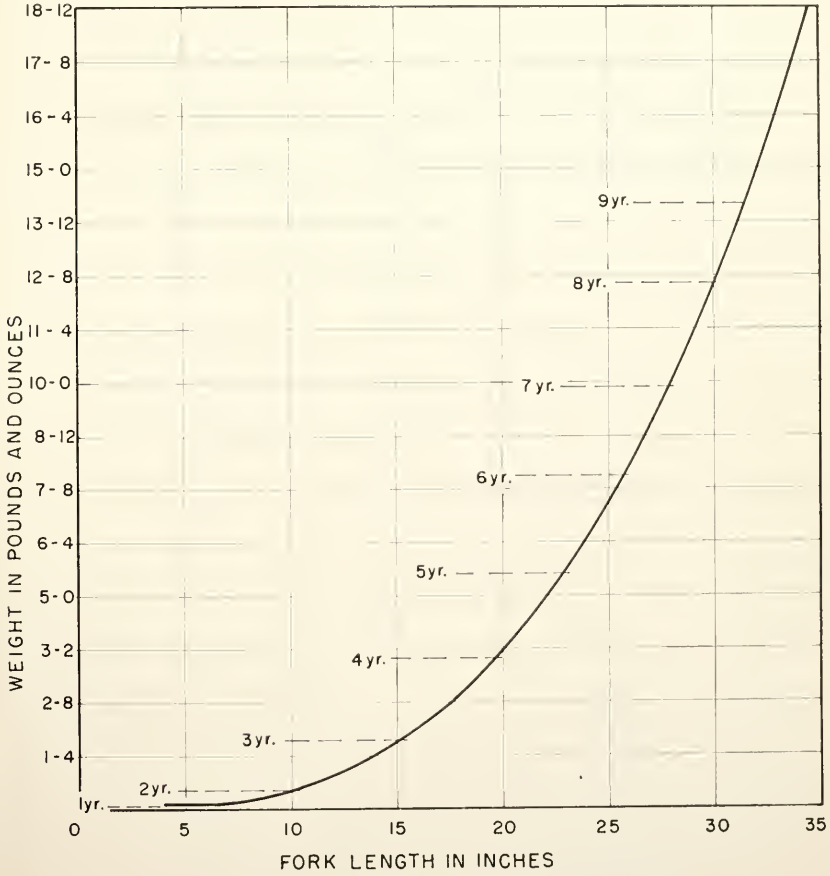

FIGURE 4. Length, weight, and age relationship of striped bass.

fluctuations cannot be determined. Moreover, data to indicate the causes of the fluctuations are not available.

Length-Weight Relationship

The length-weight relationship is described by the equation log $W = -2.1393 + 3.0038$ long L, and this line is plotted in Figure 4. The annual weight increments are shown in Figure 5. This relationship is similar to the results of three other striped bass length-weight studies (Clark, 1938; Merriman, 1941; Morgan and Gerlach, 1950).

Comparisons of Growth

Previous striped bass growth studies have been made on the Atlantic Coast (Pearson, 1938; Merriman, 1941; Tiller, 1950; Vladykov and Wallace, 1952; Stevens, 1957), and also in California (Scofield, 1931) and Oregon (Morgan and Gerlach, 1950). Reported growth rates

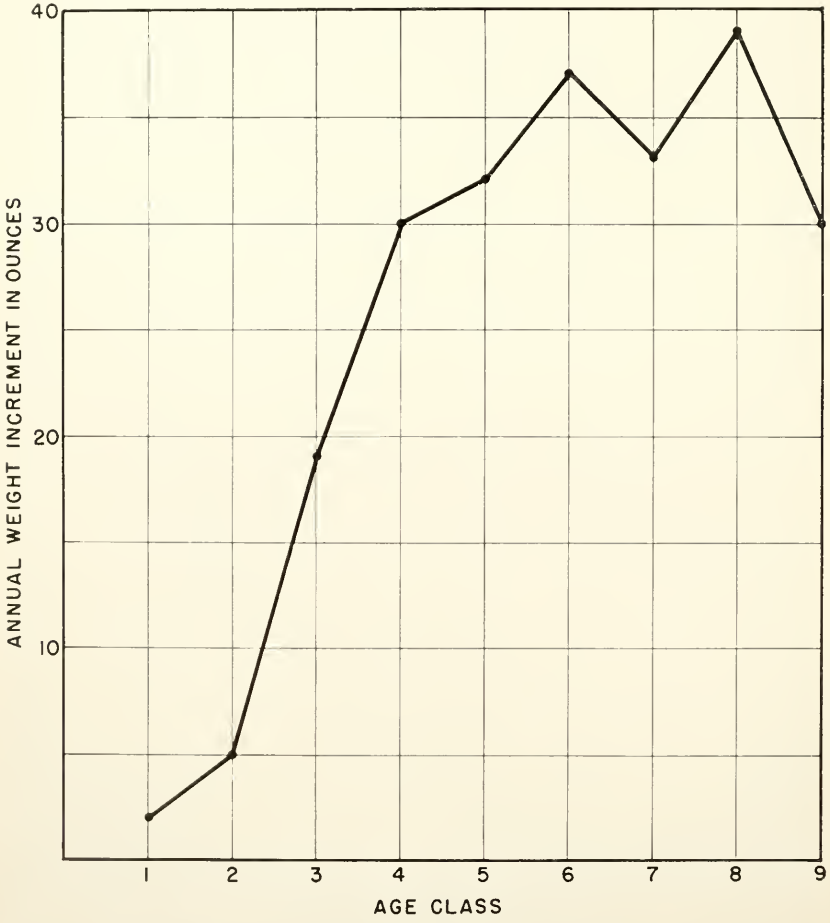

FIGURE 5. Annual weight increment of striped bass.

TABLE 1

Calculated Lengths of Male Striped Bass Collected in 1957-58

Age group	Number of fish	Fork length at capture (inches)	Calculated length at end of year of life (inches)								
			1	2	3	4	5	6	7	8	9
II	31	16.2	4.1	10.5							
III	190	19.4	4.0	9.4	15.0						
IV	89	22.4	4.1	9.9	15.0	19.5					
V	39	25.0	4.5	10.9	15.9	19.5	22.5				
VI	20	26.2	4.3	10.2	15.4	19.3	22.0	24.4			
VII	11	27.7	3.9	9.5	14.9	19.1	21.9	24.4	26.3		
VIII	3	29.0	4.0	10.8	14.8	18.4	21.7	24.3	26.2	27.7	
IX	2	31.1	3.1	10.0	15.4	19.7	22.4	25.5	27.5	29.1	30.0
Grand average calculated length			4.1	9.8	15.2	19.4	22.3	24.5	26.4	28.2	30.0
Standard error of mean			0.04	0.07	0.08	0.13	0.19	0.31	0.68	0.98	2.25
Average annual increments of growth			4.1	5.7	5.4	4.2	2.9	2.2	1.9	1.8	1.8
Number of fish	385		385	385	354	164	75	36	16	5	2

TABLE 2

Calculated Lengths of Female Striped Bass Collected in 1957-58

Age group	Number of fish	Fork length at capture (inches)	Calculated length at end of year of life (inches)								
			1	2	3	4	5	6	7	8	9
II	14	16.4	3.9	10.5							
III	150	20.0	4.1	9.5	15.3						
IV	82	23.5	4.0	9.9	15.0	19.7					
V	24	25.9	4.1	9.9	15.5	19.1	22.7				
VI	12	28.9	4.5	11.2	16.4	20.7	23.7	26.6			
VII	8	30.6	4.1	10.0	15.7	20.5	24.8	27.1	29.1		
VIII	2	33.4	5.0	12.3	16.4	20.6	24.7	27.5	29.7	31.6	
IX	3	33.9	3.8	8.9	13.9	17.7	23.3	26.9	29.9	31.5	32.9
Grand average calculated length			4.1	9.8	15.3	19.7	23.4	26.9	29.4	31.5	32.9
Standard error of mean			0.04	0.08	0.09	0.16	0.32	0.38	0.46	0.62	0.57
Average annual increments of growth			4.1	5.7	5.5	4.4	3.7	3.5	2.5	2.1	1.7
Number of fish	295		295	295	281	131	49	25	13	5	3

are seen to be generally similar to those found in the present study (Table 7), with the exception of the work of Stevens (1957). However, the latter study is not completely analogous, since it involved the landlocked population in Santee-Cooper Reservoir.

The present study shows that there has been a significant increase in the growth rates of the California bass since the work of Scofield (Tables 3 and 4). This increase occurs after the second year, and it is greater in females than in males. For females, the greatest difference is 2.8 inches at six years of age, while for males the greatest difference is 2.3 inches at both six and seven years of age. This represents approximately a 10 percent increase in length and a 25 percent increase in weight.

TABLE 3

Comparison of Growth of Male Striped Bass in 1930 and 1957-58

Year of life	Mean calculated fork length					Mean annual growth		
	1930		1957-58		Difference between 1957-58 and 1930	1930	1957-58	Difference between 1957-58 and 1930
	Number of fish	Length (inches)	Number of fish	Length (inches)				
1	35	4.2	385	4.1	—0.1	4.2	4.1	—0.1
2	35	9.9	385	9.8	—0.1	5.7	5.7	0
3	35	14.6	354	15.2	*+0.6	4.7	5.4	+0.7
4	35	17.5	164	19.4	*+1.9	2.9	4.2	+1.3
5	34	20.3	75	22.3	*+2.0	2.4	2.9	+0.5
6	18	22.2	36	24.5	*+2.3	1.9	2.2	+0.3
7	12	24.1	16	26.4	*+2.3	1.9	1.9	0
8			5	28.2			1.8	
9			2	30.0			1.8	

* Statistically significant increase in growth.

TABLE 4

Comparison of Growth of Female Striped Bass in 1930 and 1957-58

Year of life	Mean calculated fork length					Mean annual growth		
	1930		1957-58		Difference between 1957-58 and 1930	1930	1957-58	Difference between 1957-58 and 1930
	Number of fish	Length (inches)	Number of fish	Length (inches)				
1	43	4.2	295	4.1	—0.1	4.2	4.1	—0.1
2	43	9.7	295	9.8	+0.1	5.6	5.7	+0.1
3	43	14.6	281	15.3	*+0.7	4.8	5.5	+0.7
4	43	18.1	131	19.7	*+1.6	3.5	4.4	+0.9
5	43	21.3	49	23.4	*+2.1	3.2	3.7	+0.5
6	33	24.1	25	26.9	*+2.8	2.7	3.5	+0.8
7	21	26.8	13	29.4	*+2.6	2.7	2.5	—0.2
8			5	31.5			2.1	
9			3	32.9			1.7	

* Statistically significant increase in growth.

TABLE 5

Comparison Between Measured Fork Lengths of Striped Bass Collected in 1957-58 and Calculated Fork Lengths

Males			Females	
Mean length at capture (inches)	Mean calculated length (inches)	Age group	Mean length at capture (inches)	Mean calculated length (inches)
----	4.1	I	----	4.1
8.6	9.8	II	8.6	9.8
16.2	15.2	III	16.4	15.3
19.4	19.4	IV	20.0	19.7
22.4	22.3	V	23.5	23.4
25.0	24.5	VI	25.9	26.9
26.2	26.4	VII	28.9	29.4
27.7	28.2	VIII	30.6	31.5
29.0	30.0	IX	33.4	32.9
31.1	----	----	33.9	----

TABLE 6

Percentage Deviation from the Mean Annual Growth of Striped Bass, 1952-1956

	1952	1953	1954	1955	1956
Males	—1.8	+2.7	+3.6	—1.4	—1.3
Females	—17.1	+7.8	—1.9	+2.0	—8.0
Average	—9.5	+5.3	+0.9	+0.3	—4.7

TABLE 7

Growth of Striped Bass in Various Waters, Sexes Combined

	LENGTH IN INCHES					
Year of life	Present study, 1957-58; mean calculated fork lengths	Schofield (1931); mean calculated fork lengths	Pearson (1938); fork length frequency distributions	Merriman (1941); mean calculated fork length to 4 years, mean fork lengths of age classes 5 to 9 years	Morgan and Gerlach (1950); mean fork lengths of age classes	Stevens (1957); mean calculated total lengths
1	4.1	4.2	4.0	4.9	----	8.5
2	9.8	9.8	10.0	9.3	----	15.7
3	15.3	14.6	15.0	14.4	14.5	19.8
4	19.6	17.8	18.5	17.7	19.0	22.9
5	22.9	20.8	----	20.9	22.7	25.8
6	25.7	23.2	----	24.0	25.0	28.5
7	27.9	25.4	----	27.0	27.3	30.2
8	29.9	----	----	29.5	28.8	----
9	32.3	----	----	32.3	30.0	----

There are many possible causes for this increase in growth rate, but the available data are insufficient to determine which ones are responsible. One of the most logical explanations is that the competition for food has decreased, due to the decline in the numbers of striped bass during this period. This decline in the bass population is shown by the marked decline in catch per unit of effort in the striped bass sport fishery (Calhoun, 1953; Ryan, 1959; and unpublished data).

MANAGEMENT APPLICATIONS

The results of the present study are pertinent to an evaluation of the increase in the minimum size limit from 12 inches to 16 inches made in 1956. These results show that Clark's (1938) finding that bass double their weight between 12 and 16 inches is still valid. However, the present study indicates that this growth is now accomplished during a shorter period of time. Therefore, the present growth rate is even more favorable to the increase in size limit than it was thought to be on the basis of the information that was available when the size limit was changed.

The threadfin shad, *Dorosoma petenense,* was introduced into reservoirs on the Sacramento-San Joaquin river system in 1959, and is expected to become established in many of the areas now inhabited by striped bass. This study will be of value in helping to determine the effect of this introduction on the striped bass population.

SUMMARY

Striped bass collected in 1957 and 1958 were studied to determine whether significant changes in the growth rate had occurred during the last 30 years. The growth rate was determined by aging scales and back calculating the growth. The length-weight relationship was also determined.

It was found that the growth rate is similar to that found in California 30 years ago, and in most other striped bass populations. However, it does show that there has been a significant increase in the growth rate of California striped bass between the ages of III and VII during the last 30 years. This difference reaches a maximum of about 2.5 inches at ages VI and VII.

No significant changes were found in the length-weight relationship, but, because of the increased rate of growth, the mean weight of bass at a given age is greater.

The age and growth data from this study are more favorable for the size limit increases made in 1956 than the growth data available for evaluation at that time.

ACKNOWLEDGMENTS

The author wishes to thank Harold K. Chadwick for his guidance and helpful criticisms, and to acknowledge the assistance of Vincent Catania, William Kier, and Bruce Eliason, who helped collect and process data.

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THE IMPORTANCE OF THE OCEAN SPORT FISHERY TO THE OCEAN CATCH OF SALMON IN THE STATES OF WASHINGTON, OREGON AND CALIFORNIA[1]

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INTRODUCTION

Commercial fishing for salmon in the ocean began in the late 19th and early 20th centuries when it was found that both chinook *(Oncorhynchus tshawytscha)* and silver salmon *(O. kisutch)* would readily take a trolled lure (Van Hyning, 1951). Scofield (1956) noted that commercial trolling through the 1890's amounted to little until the discovery of the mild-curing process (about 1898) following which it reached quantity production about 1901. Kauffman (1951) stated that Washington inside commercial trollers gradually turned to more productive grounds offshore after 1917. These offshore trollers were exceedingly important to the economy of many small coastal ports and were instrumental in opening new small boat harbors along the coasts of Washington, Oregon, and California.

Commercial trolling licenses have shown a general increase after World War II and especially during the last few years. Part of the increase has been due to the ease in obtaining licenses in some of the states, regardless of type of boat or gear. Both commercial and sport trolling may be conducted readily from small boats which require a low original investment. The gear used is comparatively inexpensive. This manner of fishing, therefore, has attracted many hundreds of commercial and sport fishermen to waters adjacent to the coasts of the three aforementioned states.

Sport fishing for salmon in Washington's sounds, bays, harbors, and rivers also dates back to the late 19th century (Pressey, 1953). However, it was not until the early 1940's that this salt-water sport began showing signs of becoming one of the more important fisheries of this state. Scofield *(op. cit.)* mentioned that salmon trolling was practiced in California in the early 1880's by a few sportsmen. The real increase began after World War II. Prior to 1951, except for the Puget Sound region, salt water sport catches generally occurred either in or just off the various coastal river mouths during the period when runs of salmon were expected to enter the rivers on their annual spawning migration.

[1] Submitted for publication March, 1960. Prepared at the request of the Pacific Marine Fisheries Commission. Data supplied by the State of Washington Department of Fisheries, the Oregon Game Commission, the Oregon Fish Commission, and the California Department of Fish and Game. Figures by Cliffa Corson.

Prior to 1950, relatively few sportsmen had fished for salmon in the ocean. The few pioneers in these areas were generally local people using small low-powered open boats who fished the "safe" tides and then scurried to shore with their catches. The horsepower race which so radically changed the automotive field after World War II also affected manufacturers of small boat motors. The use of glass, metal, and plastics has revolutionized the boat building industry. The combination of dependable and powerful motors with larger, more seaworthy small craft has permitted the sportsman to travel to offshore fishing areas that would have been unsafe only a few years ago. These small craft have tended to outnumber the commercial boats and have invaded coastal waters that formerly had been fished exclusively by the commercial troller.

The question often arises in almost any discussion with commercial or sport fishing interests as to the importance of these two fisheries to the total ocean catch of salmon. The primary difficulty in reaching adequate conclusions has been a lack of the manpower needed to make satisfactory surveys of sport fisheries. The commercial salmon catch for the three western states is obtained relatively easily since the poundage of all fish sold must be listed on receipt sheets, copies of which are sent to the managing agency. The number of fish in the catch can then be determined by applying average weight factors collected in the field.

The estimation of the catch by sportsmen has always been fraught with difficulties. Each year the fishery may change either in area fished, duration of the fishery, or type of lure used. The program of sampling may be limited in scope because of manpower shortages. These factors, singly or in combination, may cause sampling errors which in turn may induce the catch estimate to be too large or too small. However, each of the states involved with ocean sport fisheries has developed certain methods to enumerate the catch.

In the sport fisheries two types of boats predominate: the skiff or outboard kicker boat, and the party or charter boat. The party boats usually have better angler success because of their greater cruising range and experienced professional skippers. They also carry considerably more people than the smaller limited-range outboards.

METHODS OF ESTIMATING CATCH BY SPORTSMEN

Washington

Washington does not issue a sport fishing license for the taking of salmon. The basic statistic used to estimate the sport catch depends on the area fished and the coverage desired. In and off the mouth of the Columbia River boat counts taken by the Coast Guard are used in conjunction with personal interviews as the boats bring their catches to the landing areas. This particular sampling program is conducted jointly with the State of Oregon since the Columbia River is the state boundary line. In the more northern coastal areas charter boat log books, Coast Guard boat counts, and personal interviews are utilized. In the extreme northern sector (Neah Bay), boathouse report forms are used in conjunction with interviews. Through the use of these methods, sampling intensity has been as high as 30 percent of the boats fishing in the area (Columbia River Progress Report, August-December 1956).

Oregon

Oregon requires a sport fishing license for salmon and steelhead and utilizes the punch card-interview system coupled with Coast Guard counts of boats in the areas of fishing to enumerate the catch. This method has been successful in certain areas where the fishery is not spread over great distances and a single species predominates in the catch. The Oregon punch card does not differentiate between species of salmon. Prior to 1959, it was not required to note on the punch card the number of fish caught if the catch occurred in international waters. This necessitated interview sampling which may have been sparse because of limited manpower. By legislative act in 1959, a landing importation law was enacted which requires that salmon caught in international waters be noted on the punch card when the fishermen enter the state waters.

California

California also requires a sport fishing license. In this state party boat skippers are required to send a daily log of their passengers' catches to the Department of Fish and Game. Spot checks are made of the accuracy of these reports. In 1955 and 1956 a federal aid project made a detailed study of party boat, skiff, and other ocean sport salmon catches, primarily by sampling the landings at various ports. The figures used in Table 3 were obtained from these sources. In 1955 and 1956 party boat landings represented 65 percent of the total ocean salmon sport landings. Party boat records were used to calculate the totals for other years. An assumption, based on observations but not samples, was used to make these calculations. It was: party boat landings were 90 percent of the total from 1947 through 1950, and 65 percent from 1951 on (Eldon P. Hughes, personal communication March 1959).

California also has used a post card survey method to estimate the trend of sport fishing catches during many of the years from 1936 through 1957 (Calhoun, 1950, 1951, and 1953; Skinner, 1955; and Ryan, 1959). In this method questionnaires are sent to a random sample of license holders. Post card surveys are suspect for a variety of reasons, and in this instance the federal aid study of 1955-1956 demonstrated that in 1956 the post card returns gave an estimate of the ocean salmon fishery that was nearly three times what it should have been.

OCEAN CATCH OF SALMON BY STATES

Washington

The phenomenal growth of the ocean sport fishery in Washington was further hastened by funds allocated by the Corps of Engineers for building and enlarging small boat basins. Westport, located about midway along the Washington coast, was relatively unknown prior to 1950. It is now the center of sport fishing activities and boasts one of the finest protected boat basins along the coast. Within a few minutes, fishermen leaving this small coastal town can be in a position to intercept the salmon runs moving either north or south. The ocean sport fisheries in Washington appeared relatively minor until 1952 (Table 1, Figures 1 and 2).

TABLE 1

Washington Ocean Sport and Commercial Troll Catches in Thousands of Fish and Percent Sport Catch 1947 Through 1958

Year	Commercial catch		Sport catch[1]		Total fish		Percent sport	
	Chinook	Silvers	Chinook	Silvers	Chinook	Silvers	Chinook	Silvers
1947	325	584	6	3	331	587	1.8	0.5
1948	286	746	6	3	292	749	2.1	0.4
1949	291	518	8	4	299	522	2.7	0.8
1950	257	551	17	13	274	564	6.2	2.3
1951	331	634	34	15	365	649	9.3	2.3
1952	407	843	92	30	499	873	18.4	3.4
1953	419	665	46	50	465	715	9.9	7.0
1954	384	403	71	63	455	466	15.6	13.5
1955	385	494	84	61	469	555	17.9	11.0
1956	295	706	118	140	413	846	28.6	16.5
1957	359	737	102	192	461	929	22.1	20.7
1958	270	525	84	145	354	670	23.7	21.6

[1] Columbia River sport landings have been equally divided between Washington and Oregon and are included in part herein.

The ocean sport catch for chinook salmon has ranged from a low of nearly 2 percent to a high of nearly 29 percent of the total catch during the years 1947 through 1958. Silver catches have ranged from less than 1 percent to nearly 22 percent during the same period.

Oregon

Ocean sport salmon fishing in Oregon showed nearly the same mushrooming increase as in the State of Washington. Sport fishing occurred on a minor scale for a number of years in Coos, Winchester, and Depoe bays but was negligible until 1955 (Table 2, Figures 1 and 2).

TABLE 2

Oregon Ocean Sport and Commercial Troll Catches in Thousands of Fish and Percent Sport Catch 1949 Through 1958

Year	Commercial catch		Sport catch[1]		Total fish		Percent sport	
	Chinook	Silvers	Chinook	Silvers	Chinook	Silvers	Chinook	Silvers
1949	109	173	8	13	117	186	6.8	7.0
1950	88	164	11	3	99	167	11.1	1.8
1951	212	279	10	6	222	285	4.5	2.1
1952	237	353	11	16	248	369	4.4	4.3
1953	150	278	15	13	165	291	9.1	4.5
1954	195	240	17	22	212	262	8.0	8.4
1955	307	267	59	44	366	311	16.1	14.1
1956	334	449	51	105	385	554	13.2	19.0
1957	251	551	79	124	330	675	23.9	18.4
1958	174	195	74	59	248	254	29.8	23.2

SOURCES: Commercial landings from the Oregon Fish Commission Research Laboratory in Astoria, Oregon. Sport catch estimates from Dr. John Rayner of the Oregon Game Commission, Portland, Oregon.

[1] Columbia River sport landings have been equally divided between Washington and Oregon and are included in part herein.

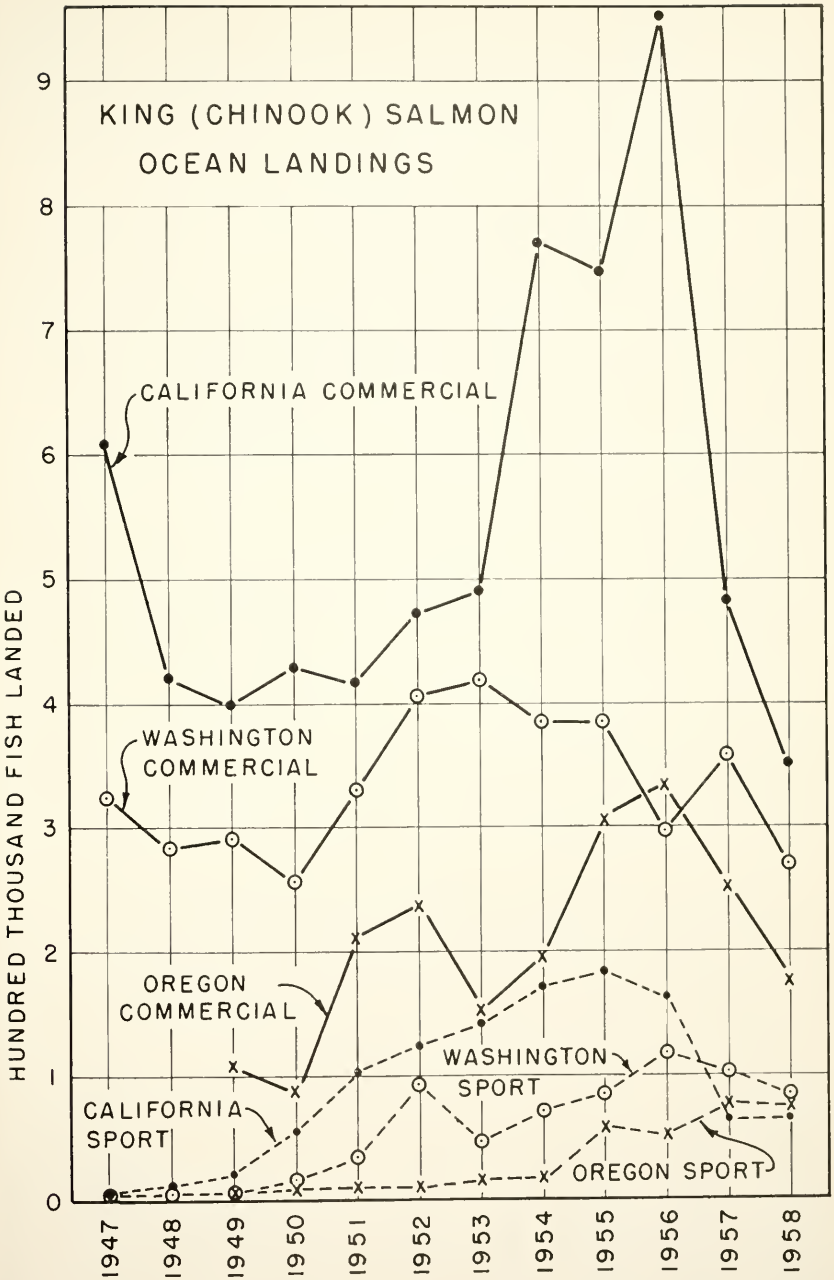

FIGURE 1. KING (CHINOOK) SALMON. Numbers of ocean caught king salmon landed by commercial and sport fishermen in Washington, Oregon, and California.

The percent ocean sport catch by species has risen from over 4 in 1952 to nearly 30 in 1958 for chinook salmon, and from nearly 2 to over 23 for silver salmon in 1950 and 1958 respectively. Silver salmon contribute the major share of the ocean sport catch in this state, averaging nearly 55 percent from 1949 through 1958. This relationship holds true in the commercial fishery also.

California

Sport fishing for salmon in California occurs, for the most part, from Monterey Bay northward. Significant catches are made in Monterey Bay, off San Francisco Bay, off Fort Bragg, and northward from Eureka. The fishery first became important at San Francisco which was and is primarily a party boat fishery. In the other areas the proportion of skiff catches is much higher. (Total landings of sport and commercial salmon are shown in Table 3 and Figures 1 and 2.)

The ratio of king to silver salmon varies from port to port and season to season, but for purposes of estimating the numbers of silver salmon for Table 3 it was assumed that the relationship found in 1955 and 1956 existed from 1947 through 1958. During those seasons 7.4 percent of the total sport landings were silvers.

Of the total salmon catch in California, the catch by the ocean sport fishery has ranged from less than 1 percent in 1947 to a high of 22 and 21 percent in 1953 and 1955 for chinook and silver salmon respectively. The dramatic increase in landings which occurred in 1951 has fallen off in 1957 and 1958.

KING *(Chinook)* SALMON

The chinook catches of all states have been combined to indicate the relative strength of the sport catch along the West Coast (Table 4). Wendler and Junge (1957) have pointed out that more than one

TABLE 3

California Ocean Sport and Commercial Troll Catches in Thousands of Fish and Percent Sport Catch 1947 Through 1958

Year	Commercial catch		Sport catch		Total fish		Percent sport	
	Chinook	Silvers	Chinook	Silvers	Chinook	Silvers	Chinook	Silvers
1947	610	87	5	0.4	615	87.4	0.8	0.5
1948	421	93	11	1	432	94	2.5	1.1
1949	400	89	23	2	423	91	5.4	2.2
1950	430	85	57	5	487	90	11.7	5.6
1951	416	58	103	8	519	66	19.8	12.1
1952	474	92	123	10	597	102	20.6	9.8
1953	490	100	141	11	631	111	22.3	9.9
1954	771	64	171	14	942	78	18.2	17.9
1955	747	56	184	15	931	71	19.8	21.1
1956	958	68	163	13	1,121	81	14.5	16.0
1957	482	89	64	5	546	94	11.7	5.3
1958	350	20	65	5	415	25	15.7	20.0

SOURCE: Salmon and steelhead investigations, Marine Resources Branch, California Department of Fish and Game, March 1959.

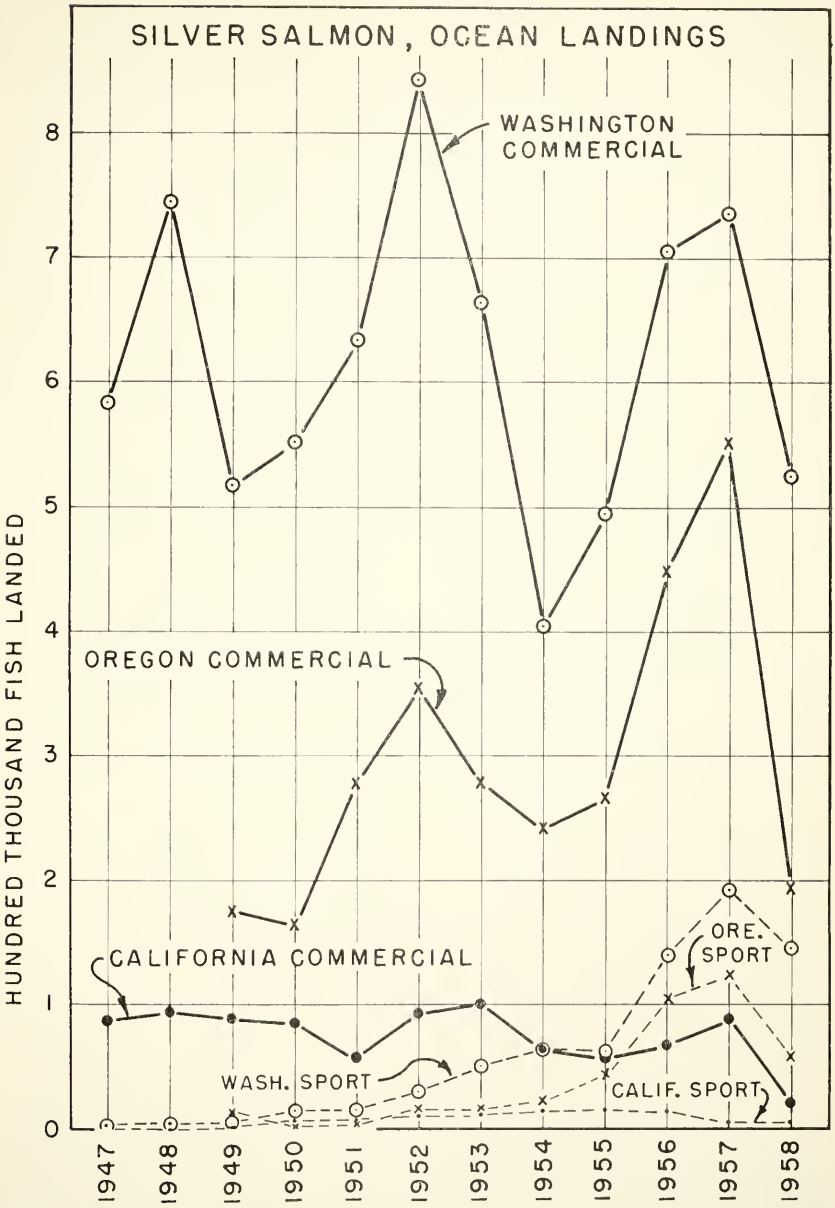

FIGURE 2. SILVER SALMON. Numbers of ocean caught silver salmon landed by commercial and sport fishermen in Washington, Oregon, and California.

year class enters the catch of both ocean troll and sport fisheries in a given year. Hence, a moving average combining at least two years was used, notwithstanding the fact that the sport fisheries operate on two, three, and possibly four year classes.

TABLE 4

Washington, Oregon, and California Combined Ocean Chinook Salmon Catches in Thousands of Fish and Percent Catch by Fishery, 1947-1958

Combined years	Commercial catch	Estimated sport catch	Total landings	Percent	
				Commercial landings	Sport landings
1947-48	1,642	28	1,670	98.3	1.7
1948-49	1,507	56	1,563	96.4	3.6
1949-50	1,575	124	1,699	92.7	7.3
1950-51	1,734	232	1,966	88.2	11.8
1951-52	2,077	373	2,450	84.8	15.2
1952-53	2,177	428	2,605	83.6	16.4
1953-54	2,409	461	2,870	83.9	16.1
1954-55	2,789	586	3,375	82.6	17.4
1955-56	3,026	659	3,685	82.1	17.9
1956-57	2,679	577	3,256	82.3	17.7
1957-58	1,886	468	2,354	80.1	19.9

Table 4 indicates that the ocean sport catch of chinook salmon is approaching 20 percent of the total catch. It was pointed out previously that both Oregon and Washington sport catches have approached or exceeded one-fourth the total ocean catch in these states. However, California sport catches were low in 1957 and 1958, which held the total percent catch for all states combined at a lower level.

SILVER SALMON

The annual catches of silver salmon have been totaled in Table 5. In this case individual years have been used since the great majority of the silver salmon landed are in their third year.

TABLE 5

Washington, Oregon, and California Combined Ocean Silver Catch in Thousands of Fish and Percent Catch by Fishery, 1947 Through 1958

Year	Commercial catch	Estimated sport catch	Total landings	Percent	
				Commercial landings	Sport landings
1947	671	3.4	674.4	99.5	0.5
1948	839	4	843	99.5	0.5
1949	780	19	799	97.6	2.4
1950	800	21	821	97.4	2.6
1951	971	29	1,000	97.1	2.9
1952	1,288	56	1,344	95.8	4.2
1953	1,043	74	1,117	93.4	6.6
1954	707	99	806	87.7	12.3
1955	817	120	937	87.2	12.8
1956	1,223	258	1,481	82.6	17.4
1957	1,377	321	1,698	81.1	18.9
1958	740	209	949	78.0	22.0

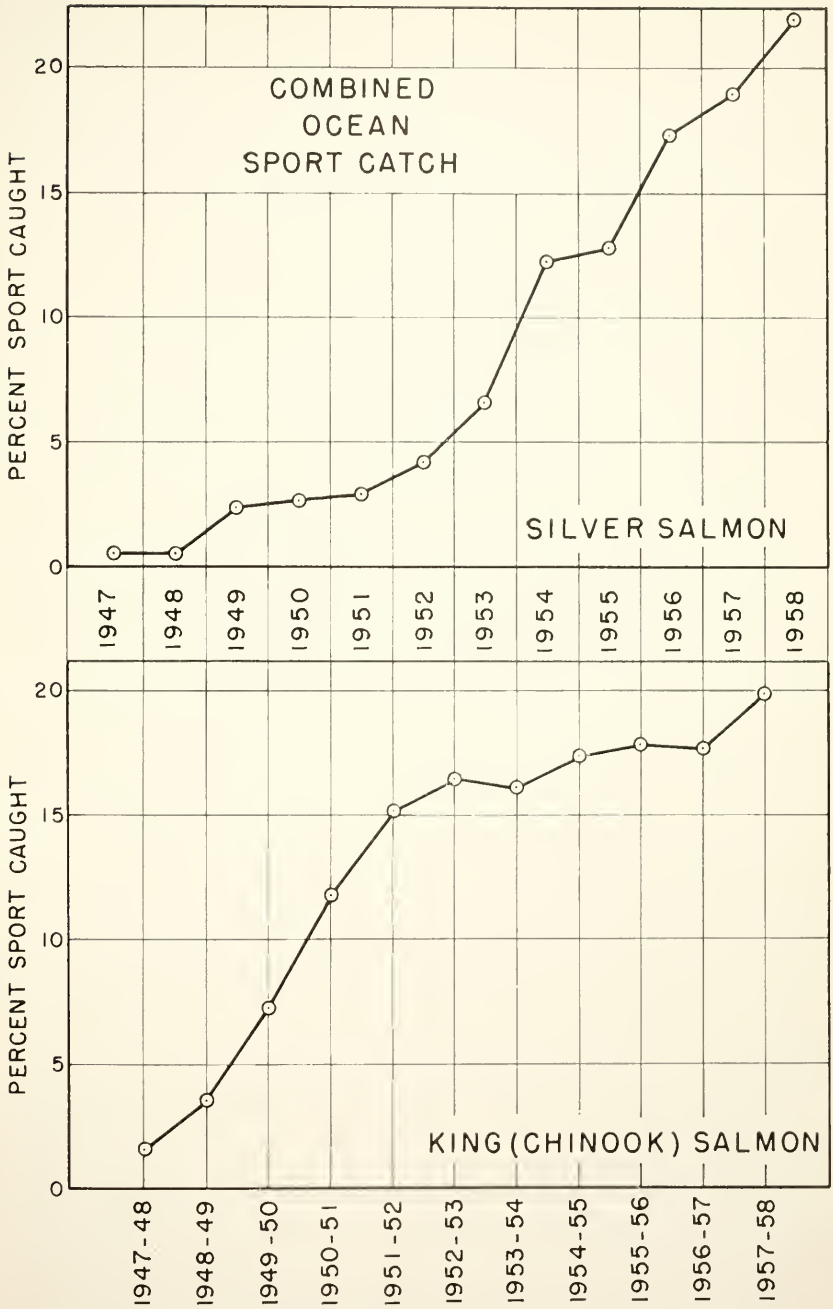

FIGURE 3. GROWTH OF THE SPORT FISHERY. Combined Washington, Oregon, and California sport catches of ocean caught salmon expressed as percent of the total ocean landings. The king salmon landings have been smoothed by a moving average of two years.

It may be observed that the sport catch of silvers is presently exceeding 20 percent of the total ocean catch. Prior to 1953, the silver salmon sport catch was minor in almost all states when greater emphasis was placed on catching the larger chinook salmon. However, with the advent of the "mooching" method of fishing which uses herring for bait, and the earlier-season fishing, silver salmon were caught in larger numbers. This, coupled with greater numbers of fisherman trips, makes the catch of this species by sport gear an important segment of the harvest.

SUMMARY OF COASTWISE SPORT CATCHES

The ocean sport catch of both chinook and silver salmon has increased phenomenally over the past 10 years and is presently accounting for over 20 percent of the total catch. There is some indication that the percent sport catch may be stabilizing on chinook salmon. The sport fisherman is extending his season in time and is tending to move into the area that normally was fished only by the commercial troller.

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TUNA TAGGING IN THE EASTERN TROPICAL PACIFIC, 1952-1959[1]

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INTRODUCTION

The California tuna industry is the most important fishery industry in the state. It depends primarily upon Pacific yellowfin tuna *(Neothunnus macropterus)* and skipjack *(Katsuwonus pelamis)*. These two compose a single fishery extending from California to Chile, and are exploited by large tuna clippers and purse seiners based in Southern California. The fishery reached an all-time high in productivity in 1950 when over 150,000 tons valued at over 45 million dollars to the fishermen were landed. Because of the value of this fishery to the economy of the State, the Department of Fish and Game has gathered basic data pertinent to its management.

One of the fundamental phases of any fishery investigation is the definition of the stock or stocks under exploitation. The southerly expansion of the tuna fishery into northern Peru in 1950-51, central Peru in 1953, and northern Chile in 1957 has increased the need to define the stocks that support the industry. Do the tuna taken from these areas constitute a single stock of fish, a stock that does not intermingle with tuna from important fishing areas off Central America and Baja California? Tagging offers the most direct method of solving this problem.

The first successful method of tagging tunas was developed by investigators of the California Department of Fish and Game in 1952. The tags, new in concept, consisted of a piece of polyvinylchloride plastic tubing looped through the flesh immediately posterior to the second dorsal fins and were developed during two field trials. Results of the first and part of the second field trial were summarized by Wilson (1953).

His report described in detail the nine tag ideas devised for the first field trial and the three tags modified from them for use in the second.

Since the early success with plastic tubing the California "spaghetti" or "loop tag" has been used by investigators throughout the United States. It has proven quite versatile, and in California has been used successfully on several species of salmon *(Oncorhynchus* spp.), steelhead rainbow trout *(Salmo gairdneri gairdneri)*, California yellowtail *(Seriola dorsalis)*, kelp bass *(Paralabrax clathratus)*, California halibut *(Paralichthys californicus)*, sturgeon *(Acipenser transmontanus* and *A. medirostris)* and many others.

[1] Submitted for publication January, 1960.

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The purpose of this report is to present the final results of the second field trial from October, 1952 through April, 1954, and results of the regular tuna tagging program commencing in May, 1954 and terminating in May, 1959. Previous to our initial tagging experiments, little concrete information was available concerning migrations, growth, and population units of tuna that support the eastern Pacific fishery. Information obtained from our tagging program will be of value to other governmental agencies investigating them.

THE SECOND FIELD TRIAL

Tags Used

Information obtained from the first field trial was used in the development of three tags (Types E, F, and G) tested during the second trial.

Type E was constructed of a three-inch piece of No. 20, white, XTE-30 Fibron polyvinylchloride tubing. Upon this the "return" legend was inscribed in black vinylite ink manufactured by the California Ink Company, Los Angeles, formula number 104N5A2. The legend tubing was then drawn into a 12-inch piece of larger tubing, No. 14 XTE-30 colored transparent Fibron. A piece of Type 302 stainless steel wire was next drawn through the whole unit and each end bent back one-quarter inch. The tubing ends were then heat-sealed with an electric iron. When applied to the fish the ends were twisted together (Figure 1).

Type F was similar to Type E except that 27-pound-test braided nylon fishing line was run through the assembly in place of the stainless steel wire. The ends of the fishing line were tied in a square knot when applied (Figure 1).

Type G was constructed of 12-inch lengths of No. 14 XTE-30 transparent Fibron polyvinylchloride tubing. Through this was run a 19-inch piece of No. 20, white, XTE-30 Fibron tubing. The "return" legend was printed on the center of the inside tubing. To secure the tag the tubing ends were tied in a figure-eight knot drawn tight against the ends of the outside jacket and neatly trimmed (Figure 1).

Plastic materials for all three tags were manufactured by the Irvington Varnish and Insulator Company, Irvington, New Jersey. The outside and inside diameters of their No. 20 tubing are .066 and .034 inches respectively. Size No. 14 tubing is .098 inches outside diameter and .066 inside.

Early in the second field trial evidence began to accumulate indicating that Type E should be abandoned. Difficulty of construction, bulkiness, and low return rate all combined to cause its removal from the field trial. We felt that its heavy weight would cause abrasion to the finlets; and furthermore, a number of Type E tags placed on yellowtail had untwisted (Collyer, 1954).

Types F and G were shortened after a number of recoveries during the second field trial made it increasingly apparent that they were too long. Type F was shortened to nine inches and the outside jacket of Type G to 10 inches.

Techniques

All of the tags used in the second field trial were applied by means of hypodermic-like needles made from stainless steel tubing. The inside diameter of the needle was such that the end of the tag rode secure inside and was carried through the flesh when the needle was inserted into the fish. After removing the needle, the tag was pulled through, centered, and the ends secured.

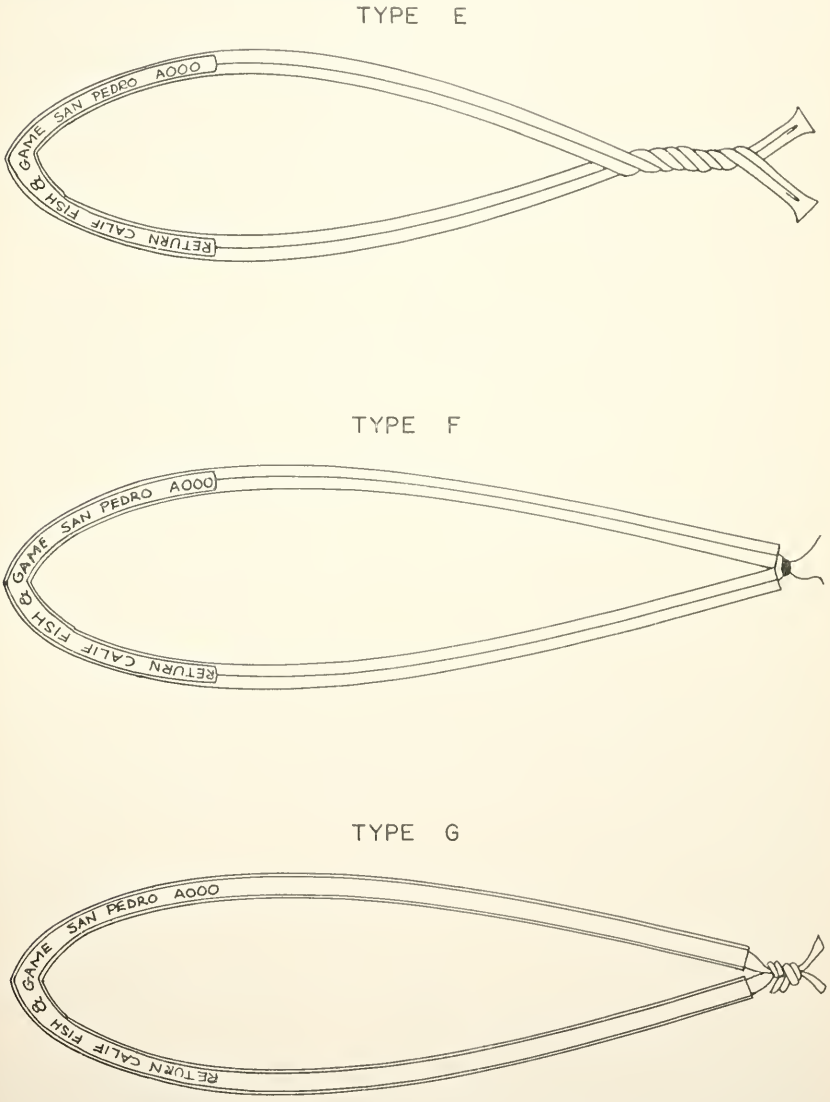

FIGURE 1. Tag Types E, F, and G used in the second field trial.

One of the major problems inherent in tagging tunas is to remove the fish from the water and affix the tag and return it to the water before a death spasm takes place. Results of the first field trial demonstrated that with careful methods some of the tunas would survive. All initial work was done aboard the department's research vessel *N. B. SCOFIELD* where sufficient help, space and facilities were available for experimentation. During the second field trial much of the tagging was done aboard commercial tuna clippers, a very satisfactory and economical method because of the fine cooperation received.

We had found from experience that at least two men are needed to tag tuna efficiently aboard commercial clippers. The tagger and his sponge-rubber-lined tagging cradle should be located near the stern on the starboard side away from the fishermen in the racks on the port side. The second man usually fishes from one of the stern racks and is able to swing fish gently around to the tagger. The tagger then quickly affixes the tag, measures the fork length of the fish and releases it into the water. Records are kept on plastic sheets on which tag numbers were entered in advance.

Results

During the second field trial 4,204 yellowfin tuna and 2,839 skipjack were tagged (Table 1) throughout the tropical commercial fishing area, with the majority released off Baja California and South America. Attempts were made to test tag Types F and G by tagging in alternate lots of from 5 to 15 tags each. Because of numerous problems encountered in tagging at sea and poor availability of materials, it was not possible to alternate types completely until the latter part of the trial.

In order to compare recovery rates of Type F and G tags, the data used in Table 1 were resummarized to include only those cruises on which both types were used (Table 2). Recoveries favored the Type G tag for both yellowfin tuna and skipjack. A Chi-square test showed significant differences in returns for both yellowfin tuna and skipjack ($P < .05$).

The apparent superiority of the Type G tag, as used in the second field trial, was probably due more to its greater visibility than to basic structural differences, since Type F tags have held secure on albacore migrating across the Pacific during periods of liberty up to 325 days (Ganssle and Clemens, 1953, Blunt, 1954). Most of the Type F tags used during the second trial had to be constructed of clear polyvinylchloride tubing, (the only material available) giving them a lower visibility factor than the white Type G.

On the basis of the second field trial Type G was selected as the most efficient and a full-scale tagging program was undertaken.

MODIFICATIONS AND EXPERIMENTS SINCE SECOND FIELD TRIAL

Material

Marking Ink and Tag Construction

Previous to our initial tagging experiments in 1952, an ink satisfactory for marking vinylite plastic had not been formulated. With the manufacture of vinylite ink, Formula 104N5A2, it was possible to inscribe an apparently resistant legend and number on each tag. The

TABLE 1

Second Field Trial
Summary of Releases and Recoveries of Types E, F, and G Tags—Trips 52S6 to 54C2

Tag		Yellowfin				Skipjack			
Type	Color	Number tagged	Number recovered	Percent recovered	Days out	Number tagged	Number recovered	Percent recovered	Days out
E	Blue	234	3	----	38–254	40	0	----	----
	Red	309	0	----	----	153	0	----	----
	Subtotal	543	3	0.55	----	193	0	----	----
F	Clear	1,064	12	----	3–229	1,103	7	----	2–34
	Blue	242	0	----	----	81	0	----	----
	Red	22	0	----	----	----	----	----	----
	Yellow	534	1	----	33	153	0	----	----
	Subtotal	1,862	13	0.70	----	1,337	7	0.52	----
G	Blue	540	9	----	25–372	198	0	----	----
	White	1,259	14	----	1–373	1,111	18	----	1–123 or 160
	Subtotal	1,799	23	1.28	----	1,309	18	1.38	----
	Grand total	4,204	39	----	----	2,839	25	----	----

TABLE 2

Releases and Recoveries During Second Field Trial Using Type F and G Tags

Tag type	Yellowfin Tuna			Skipjack		
	Tagged	Recovered		Tagged	Recovered	
	Number	Number	Percent	Number	Number	Percent
F	1,844	9	0.49	1,335	7	0.52
G	1,799	23	1.28	1,309	18	1.38

legend proved adequate when protected by a transparent outer jacket and placed at the center of the tubing (that part embedded in the fish) to prevent fading.

Midway through the regular tagging program it was felt that removal of the jacket from Type G tags would simplify them and increase tagging speed. This was done in 1956 (Cruise 56S1 Table 6) when an ink, Formula 104N5A4, considerably more resistant to light, became available.

Plastic Tubing

Shortly after the onset of the regular tagging program it became evident that the vinylite in recovered tags had lost some of its flexibility. Manufacturers indicated that this probably was caused by the leaching out of the plasticizer, the chemical component in vinylite responsible for softness and flexibility. This partial loss of flexibility, however, did not appear to have affected the efficiency of the tags. Examination of numerous tags on fish that had been at liberty for periods between one and two years, indicated the material definitely was not brittle, and still retained satisfactory flexibility.

Experience with yellow vinylite tags during the early part of the program indicated the color faded considerably, even while on fish at liberty for periods shorter than three months. In 1957, an improved yellow, Resinite X-270-I (vinylite), was put on the market by the Borden Company of Santa Barbara, California. This material was somewhat similar to XTE-30 but was considerably softer and had been formulated to retain flexibility longer. Starting in November 1957, all tags were manufactured with it.

Methods

Tagging techniques used during the regular program basically were similar to those used during the second field trial (Wilson, 1953). A rather important innovation in 1954 was the placing of a wet burlap sack or cloth over the fish's head to aid in quieting it during the tagging.

Tagging needles also were modified slightly. During the second field trial a needle of stainless steel tubing with the end ground to a sharp hypodermic-like point was used to insert the tag in the fish. The sharp edges of this needle cut as it pierced the flesh. To alleviate this, a

stainless steel rod was forced into one end of the steel tube and then ground to a sharp rounded point. This solid-point needle eliminated much of the cutting of tissue during tagging and resulted in reduced bleeding.

Detection of Tagged Fish

To publicize the tagging program posters in Spanish and English were distributed throughout the fishing ports and canneries of the United States, Mexico, and Central and South America.

The nature of the fishery is such that individual tuna are handled at least once before being weighed at the cannery, after which there is at least one additional handling before cooking and canning. Between the actual removal of the tuna from the sea by the fishermen and this final process there are numerous additional instances where tagged fish could be detected by both fishermen and cannery personnel. Fishermen often notice tagged fish lying on deck before they are passed into the refrigerated wells for storage. Cannery personnel also have returned tags to us that were first observed on fish on a conveyor in transit to the cutting and cleaning line.

Despite these many opportunities for recovering tagged fish it became evident early in the program that a substantial number of tags were not being detected and thus were lost. Fishermen reported numerous sightings of tagged fish, but due to the arduous and often hurried working conditions aboard tuna vessels many were never recovered—even when personnel were assigned to look for them during unloading at the cannery. Unknown to crew members, tagging personnel "salted" 16 tagged fish in selected storage wells. Of these 16, only six were subsequently recovered; four by cannery personnel, and two by fishermen. The other 10 were never seen again. These findings indicated a high tag loss during handling and processing, but it probably would have been even higher had we not used some yellow tags (Table 3). The better recovery rate for yellow tags is likely due to the better visibility of this color (Lahr *et al.*, 1959).

Field Testing

Experiments testing the visibility of different colors were conducted in 1956 and 1957. Alternating lots (five each) of red, white, and blue tags were released (Table 4). There was no indication that red or blue gave improved returns over the standard white tag.

TABLE 3

Recoveries of Tagged Tuna Planted in Storage Wells at Sea

Tag color	No. planted	No. recovered	No. lost
Red	3	1	2
White	7	1	6
Blue	1	0	1
Yellow	5	4	1
Totals	16	6	10

TABLE 4

Releases and Recoveries of Tuna Tagged During an Experiment Using Red, White, and Blue Tags

Cruise[1]	Red tags		White tags		Blue tags	
	Tagged	Recovered	Tagged	Recovered	Tagged	Recovered
56C3	224	5	218	1	219	3
56C4	263	2	265	3	265	3
56C5	304	1	304	2	302	5
57C1	200	1	201	1	196	1
57C4	273	1	257	2	94	0
Totals	1,264	10	1,245	9	1,076	12

[1] See Table 6.

Dart Tag Experiments

Since the early stages of the program dart-type tags had been seriously considered because of their simplicity and speed and ease of application. It was not until late 1955, however, that we were able to test them. During an exploratory oceanographic and longline fishing cruise (No. 55S5), as a part of expedition *Eastropic*, a total of 72 yellowfin, skipjack, and bigeye tuna was tagged alternately with dart and Type G "spaghetti" tags. There were no recoveries from these, probably due to the fact the fish were caught on trolling lines and released throughout a very large area in the eastern tropical Pacific. The dart tags had been obtained through the courtesy of the Woods Hole Oceanographic Institution. Dart tags of various other types were used in limited quantities in 1957 and 1958 but none was recovered.

Yamashita and Waldron (1958) reported good results from an all-plastic dart tag used in Hawaiian waters in 1957. Recovery rates up to 13 percent were realized from two lots of about 5,000 skipjack.

In early 1959, we field tested a FT-2 dart tag manufactured by the Floy Tag Company of Seattle, Washington. It has a solid dart head one inch long constructed of Zytel nylon. Attached to this is a six-inch piece of No. 18, EP-2, yellow vinylite tubing manufactured by the Borden Company of Santa Barbara, California (Figure 2).

Both yellowfin and skipjack were tagged alternately with FT-2 dart tags and Type G "spaghetti" tags off the coasts of Peru and Central America during Cruise 59C1 (Table 5). The dart tag was applied to the fish with a hollow stainless steel needle. They were pushed about one inch into the flesh near the posterior portion of the second dorsal fin base. Skipjack recoveries were overwhelmingly in favor of the dart tag. Since the tag types were released alternately it is believed the differences in recovery rates indicate a lower tagging mortality resulting from the dart tag. No yellowfin were recovered.

TAGGING RESULTS

Areas of Tagging

Due to the vagaries of fishing it was not possible to release tags in selected areas. In general, however, the areas exploited by tuna fishermen go hand-in-hand with the seasons of the year. During winter, most

TABLE 5

Result of Comparing Returns of Yellow Dart Tags (FT-2) With Yellow Spaghetti Tags (Cruise 59C1)
Recoveries Through Nov. 30, 1959

Area	Yellowfin tuna				Skipjack			
	Dart tags		Spaghetti tags		Dart tags		Spaghetti tags	
	Released	Recovered	Released	Recovered	Released	Recovered	Released	Recovered
Gulf of Tehuantepec	11	--	11	--	--	--	--	--
Central America	24	--	22	--	1	--	3	--
Gulf of Panama	12	--	11	--	1	--	2	--
Ecuador-Colombia	2	--	1	--	2	--	2	--
Gulf of Guayaquil	3	--	3	--	7	1	7	--
Peru (North)	5	--	1	--	742	19	695	2

fishing is conducted in the vicinity of the Galapagos Islands and off Central and South America. In the spring, fishing increases off Central America and Mexico and by summer the fleet concentrates off Baja California. In recent years, substantial tonnages of yellowfin and skipjack have been taken during all months off Baja California.

Some yellowfin and skipjack were tagged and released from tuna clippers in all of the major fishing areas except the Gulf of California. The Gulf of California produces good catches of relatively large yellowfin tuna, but they have traditionally been exploited more efficiently by the purse seine fleet. Due to the limited and sporadic fishing in the vicinities of Clipperton, Cocos and Malpelo Islands few tags were released at these locations.

Though cooperation of the tuna fleet was excellent during the program, scheduling of tagging trips was hindered by labor strikes, tieup of vessels for economic reasons, inability of small clippers to take two extra men and a shortage of tagging personnel. Despite these hindrances an average of four tagging trips was taken aboard commercial vessels each year. Additional tuna tagging was conducted aboard the research vessel *N. B. SCOFIELD* in conjunction with albacore and yellowtail work. The 39 tagging trips since the inception of the program are listed in Table 6.

During both the experimental phases and our regular tagging program 27,478 yellowfin tuna and skipjack were tagged in the eastern tropical Pacific. To show these diagramatically, the number of fish tagged and released in each one-degree square has been listed on the three charts covering the range of the fishery (Figures 3a, b, c and 4a, b, c). The number of recoveries, through November 30, 1959, from fish tagged in each one-degree square has been entered above the number tagged. Detailed information concerning month and year of tagging and recovery is presented in Appendices A, B, C and D.

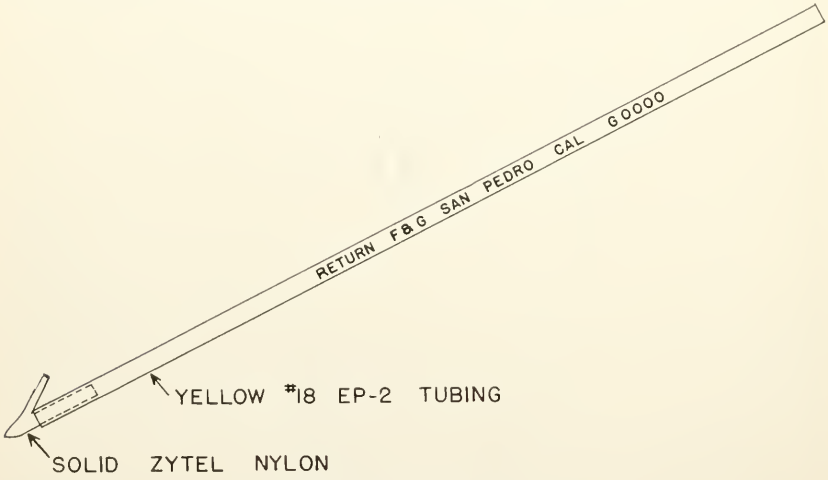

FIGURE 2. Type FT-2 dart tag.

TABLE 6

Summary of Tagging Cruises 1952 Through 1959

Vessel	Cruise number	Principal area of tagging	Departure date	Return date	Yellowfin tuna		Skipjack	
					Number tagged	Number recovered	Number tagged	Number recovered
N. B. SCOFIELD	52S2	Coast of Mexico	2/15/52	3/13/52	111	3	1	0
N. B. SCOFIELD	52S3	Coast of Mexico	4/ 7/52	5/ 7/52	241	1	0	0
N. B. SCOFIELD	52S6	Baja California	10/ 6/52	10/31/52	277	9	105	0
INTREPID	52C1	Central America-South America-Galapagos Islands	10/25/52	2/11/53	1,139	3	499	0
SOUTHERN PACIFIC	53C1	Gulf of Tehuantepec	3/11/53	4/17/53	157	0	61	0
N. B. SCOFIELD	53S2	Coast of Mexico	4/21/53	5/15/53	26	0	23	0
WESTERN MONARCH	53C4	Baja California	5/ 1 53	6/30/53	18	4	2	0
DEFIANCE	53C3	Baja California-Revilla Gigedo Islands	6/ 6 53	8/ 8/53	930	14	64	0
VIRGINIA R.	53C2	Baja California	6/ 8/53	7/31/53	218	4	581	20
N. B. SCOFIELD	53S4	Baja California	8/ 5/53	8/26/53	3	0	4	0
SARATOGA	54C1	Galapagos Islands-Central America-Mexico-Peru	1/18/54	4/10/54	704	3	430	1
MAYFLOWER	54C2	Galapagos Islands-Central America-South America	2/13/54	6/ 6/54	731	2	1,069	4
PAOLINA T	54O5P	Baja California	5/ 4/54	6/ 4/54	1	0	0	0
PAOLINA T	54O7P	Baja California	7/ 1 54	7/ 0 54	10	1	4	0
PAOLINA T	54O9P	Baja California	9/14 54	10/19/54	7	0	5	0
N. B. SCOFIELD	54S4	Baja California	8/ 2/54	10/ 1 54	0	0	3	0
SOUTHERN PACIFIC	54C3	Central America-Peru-Galapagos Islands	9/ 2 54	11/11 54	263	10	718	2
MAYFLOWER	54C4	Galapagos Islands-Gulf of Guayaquil	10/23/54	12/29/54	479	4	1,037	4
N. B. SCOFIELD	55S1	Mexico-Central America	1/ 5/55	3/ 1/55	549	2	28	0
VIRGINIA R.	55C1	Mexico-Central America	2/ 3/55	4/30/55	1,015	4	18	0
OCEAN PRIDE	55C2	Galapagos Islands-Central America	2/15/55	4/19/55	251	0	795	1
SOUTHERN PACIFIC	55C4	Baja California-Revilla Gigedo Islands	8/28/55	9/27/55	476	17	166	2
N. B. SCOFIELD	55S5[1]	Mexico-Central America	9/29/55	11/30/55	65	0	3	0
N. B. SCOFIELD	56S1	Mexico	1/10/56	3/10/56	22	0	0	0
HEROIC	56C1	Mexico-Revilla Gigedo Islands	3/ 4/56	5/24/56	140	0	244	0
SOUTHERN PACIFIC	56C2	Las Tres Marias Islands	5/15/56	6/17/56	48	0	74	0
LUCKY STAR	56C3	Baja California-Revilla Gigedo Islands	7/ 2/56	8/ 3/56	246	3	415	6
ELSINORE	56C4	Revilla Gigedo Islands-Baja California	7/21/56	8/18/56	26	3	767	5

TABLE 6—Continued

Summary of Tagging Cruises 1952 Through 1959

Vessel	Cruise number	Principal area of tagging	Departure date	Return date	Yellowfin tuna		Skipjack	
					Number tagged	Number recovered	Number tagged	Number recovered
SUN PACIFIC	56C5	Las Tres Marias Islands-Gulf of California	10/28/56	12/ 9/56	99	2	811	6
CHALLENGER	57C1	Central America-South America-Mexico	1/ 6/57	4/25/57	525	2	72	1
CONSTITUTION	57C2[1]	Mexico-Central America	1/23/57	3/22/57	872	2	127	0
CAPE FALCON	57C3	Central America-South America-Mexico	5/ 4/57	7/30/57	490	0	588	3
SOUTHERN PACIFIC	57C4	Mexico-Gulf of Tehuantepec	5/13/57	7/11/57	624	3	0	0
SOUTHERN PACIFIC	57C5[1]	Central America-South America-Mexico	11/ 4/57	2/11/58	435	2	795	2
RUTHIE B	57C6	Peru-Chile-Central America	11/12/57	3/15/58	135	1	312	6
INDEPENDENCE	58C1	Baja California-Revilla Gigedo Islands	4/30/58	7/15/58	1,054	123	659	59
CAPE BEVERLY	58C2	Baja California	6/30/58	9/ 8/58	437	9	962	13
VALIANT	58C3	Peru-Ecuador-Colombia	8/18/58	11/25/58	283	32	1,360	80
CONSTITUTION	59C1[1]	Peru-Central America-Ecuador-Colombia	3/ 5/59	5/23/59	106	0	1,463	22
				Total	13,213	263	14,265	237

[1] Cruise 55S5 includes 37 yellowfin and 2 skipjack tagged with dart tags; Cruise 57C2 includes 108 yellowfin and 22 skipjack tagged with dart tags; Cruise 57C5 includes 92 yellowfin and 206 skipjack tagged with dart tags; Cruise 59C1 includes 57 yellowfin and 753 skipjack tagged with dart tags.

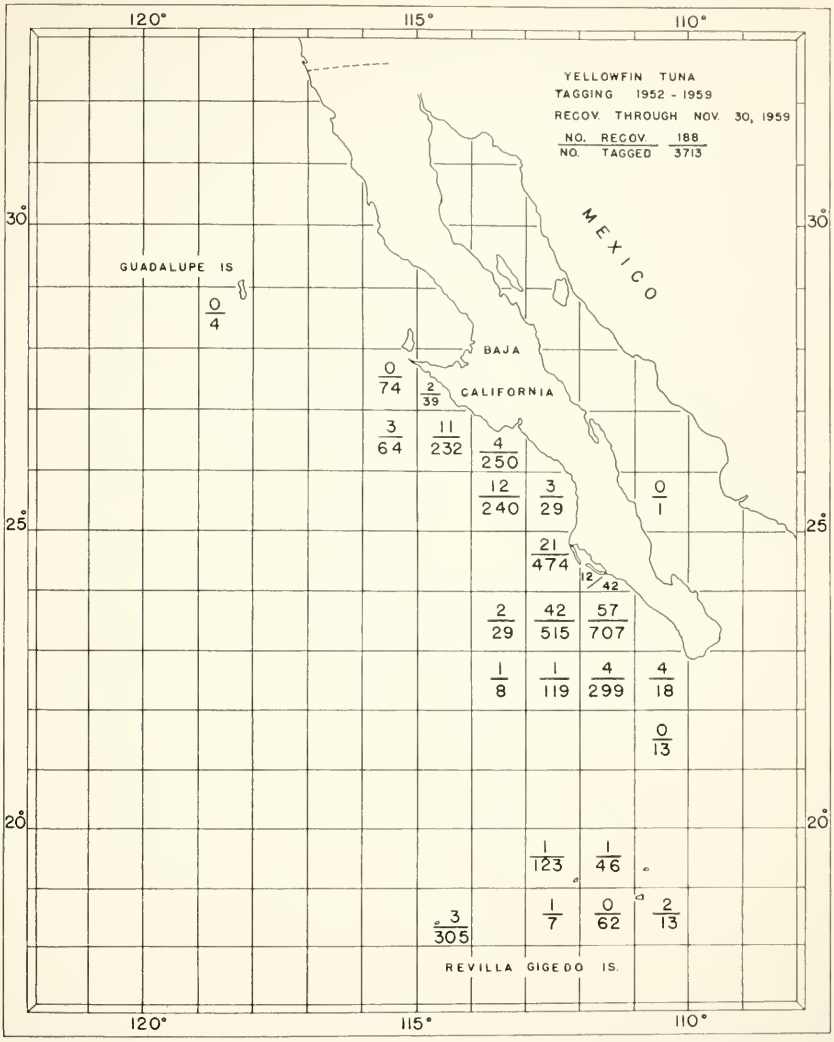

FIGURE 3a. Yellowfin tuna tag lots by one degree square of tagging off Baja California and the Revilla Gigedo Islands. The number recovered from each lot is indicated over the number tagged. Recaveries were not necessarily made within the degree square of tagging.

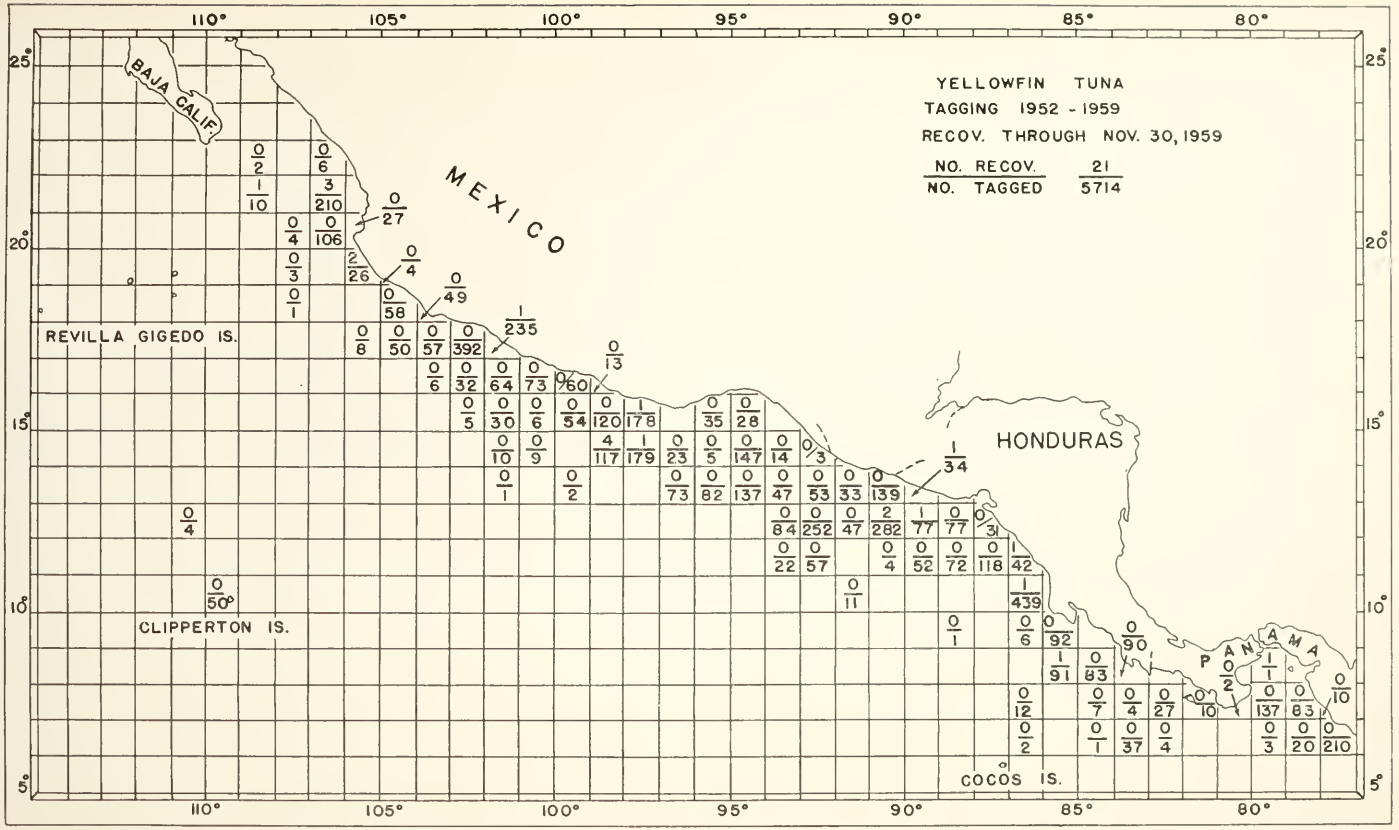

FIGURE 3b. Yellowfin tuna tag lots by one degree square of tagging off Mexico and Central America. The number recovered from each lot is indicated over the number tagged. Recoveries were not necessarily made within the degree square of tagging.

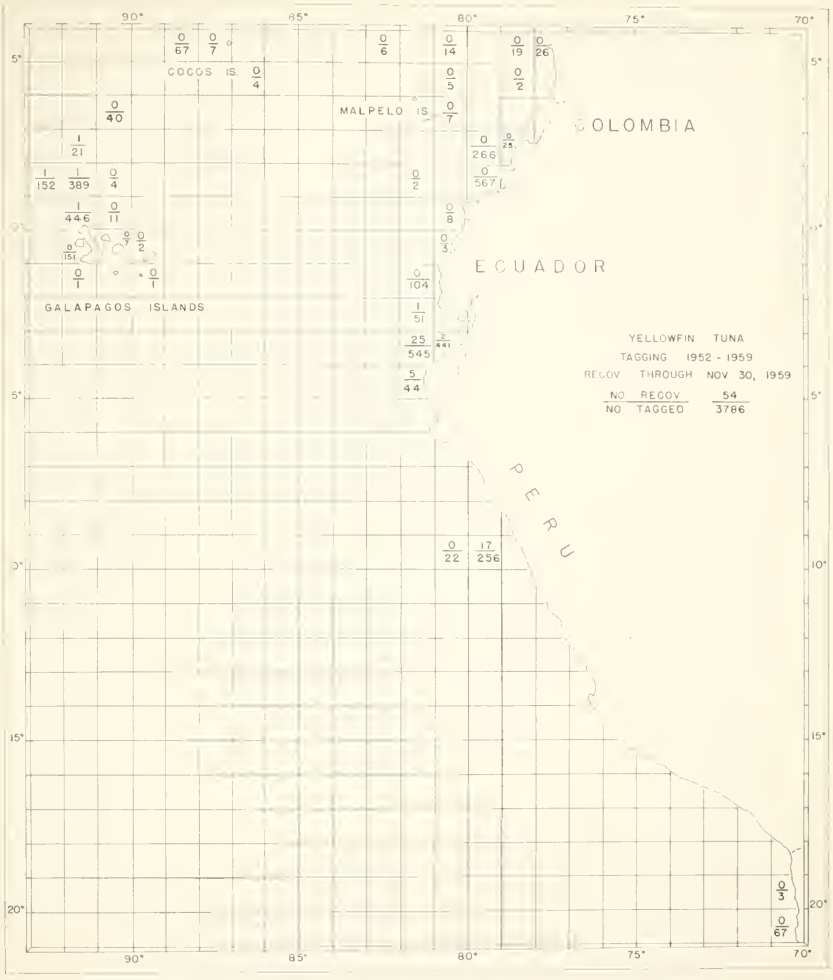

FIGURE 3c. Yellowfin tuno tag lots by one degree square of tagging off South America and the Galapagos Islands. The number recovered from each lot is indicated over the number tagged. Recoveries were not necessarily made within the degree square of tagging.

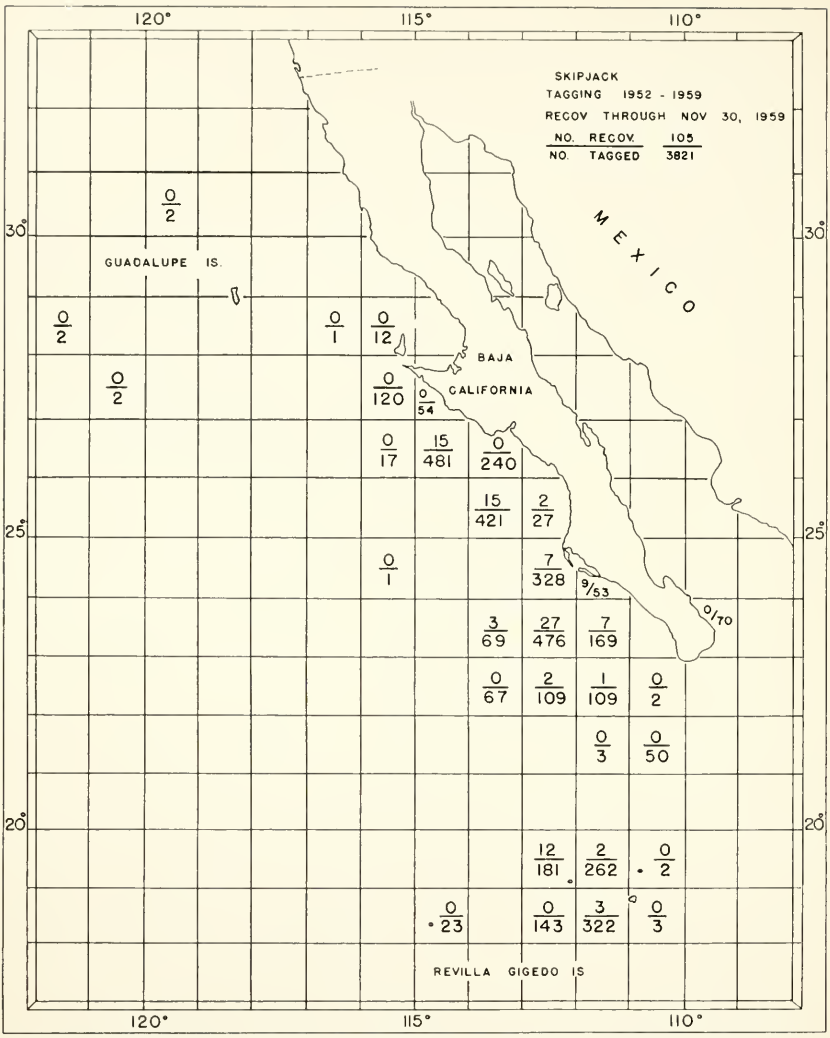

FIGURE 4a. Skipjack tag lots by one degree square of tagging off Baja California and the Revilla Gigedo Islands. The number recovered from each lot is indicated over the number tagged. Recoveries were not necessarily made within the degree square of tagging.

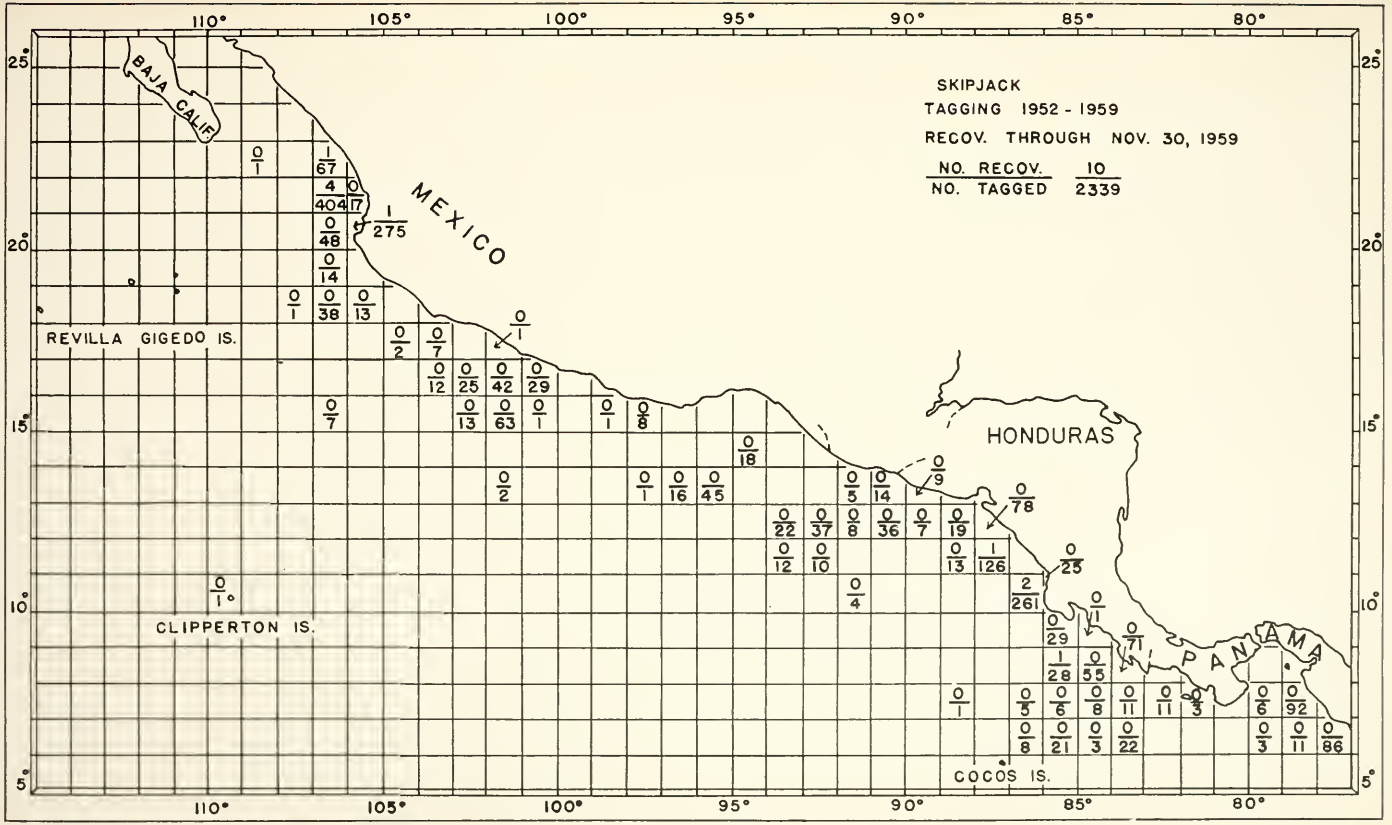

FIGURE 4b. Skipjack tag lots by one degree square of tagging off Mexico and Central America. The number recovered from each lot is indicated over the number tagged. Recoveries were not necessarily made within the degree square of tagging.

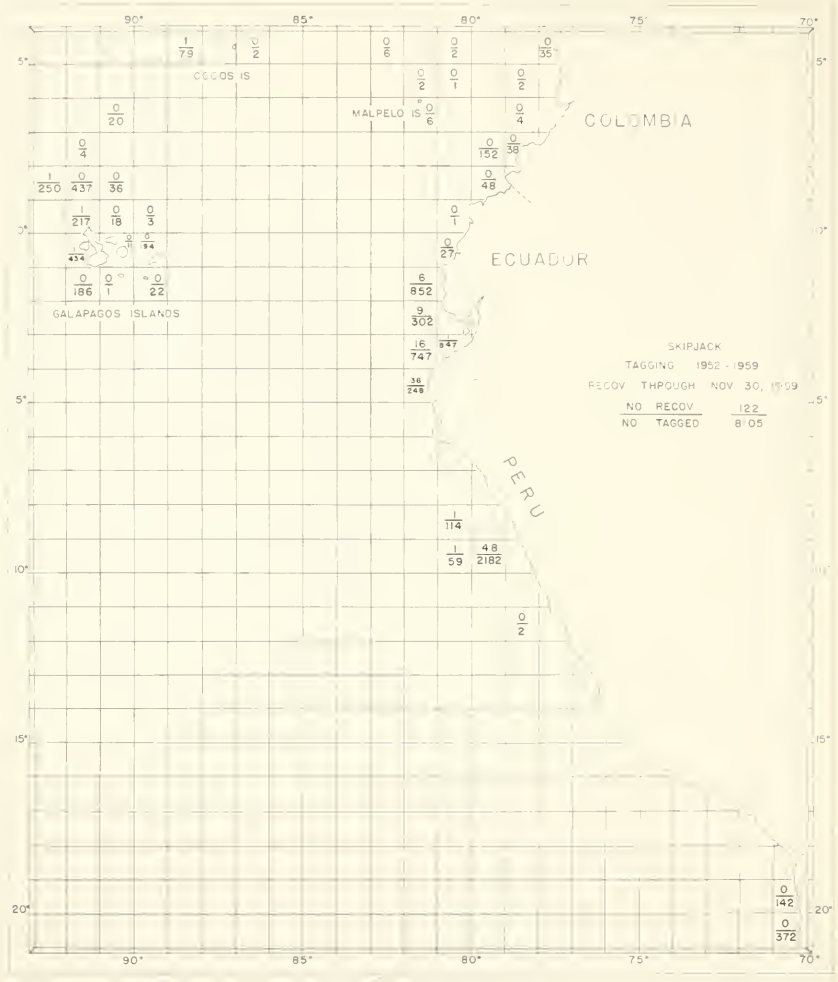

FIGURE 4c. Skipjack tag lots by one degree square of togging off South America and the Galapagos Islands. The number recovered from each lot is indicated over the number tagged. Recoveries were not necessarily made within the degree square of tagging.

Recoveries of Tagged Yellowfin Tuna

Through November 30, 1959, 263 of 13,213 tagged yellowfin tuna were returned. They had been at liberty from one to 842 days and demonstrated straight line movements up to 1,025 miles. To represent pictorially a summary of tagged yellowfin movements by periods of the year, fish recovered 75 or more miles from point of tagging were plotted on charts encompassing the range of the eastern Pacific tunas (Figures 5, 6, and 7). Detailed information for every recovery can be found in the appendices.

At the northern extremity of the fishery all of the within-season recoveries of fish tagged during May demonstrated a definite northward movement. Two even moved from the Revilla Gigedo Islands to Baja California (Figure 5a). One of the off-season recoveries (January-April) was captured in the Gulf of California. Recoveries of fish tagged during June indicated northerly movements, with one migrating from the Revilla Gigedo Islands to the mainland of Baja California (Figure 5b). Most of the fish tagged during July also moved north with only four moving south (Figure 5c). Of those moving south, one traveled from Baja California to the Revilla Gigedo Islands. Fish tagged during September and October moved southward (Figure 5d).

Movements of tuna tagged off Mexico and Central America were considerably more spectacular in that several traveled straight line distances greater than 1,000 miles (Figure 6a). All recoveries of fish tagged in these areas during February, March and April demonstrated northerly migrations. An important feature is the movement of four yellowfin tuna from the vicinity of the Gulf of Tehuantepec to the Gulf of California, Baja California and the Revilla Gigedo Islands. These four were tagged in February within a few miles of each other; the first was recovered in the Gulf of California in May, the second off Baja California in August, and the third and fourth near the Revilla Gigedo Islands in October and November. Other significant recoveries were two fish tagged off Central America which crossed the Gulf of Tehuantepec and were recaptured off Mexico. Recoveries of fish tagged in June and December appear in Figure 6b. One fish tagged in June was of particular significance in that it demonstrated evidence of a migration between the Mexican mainland and an offshore island. The best information available from the recovery vessel indicates it probably was caught at Clipperton Island, but there is a slight possibility it was caught at New Clarion Bank near the Revilla Gigedo Islands.

A yellowfin tagged north of the Galapagos Islands in March moved to the Gulf of Guayaquil (Figure 7a), and two tagged in October in the vicinity of the Gulf of Guayaquil moved south to central Peru. Those tagged during November and December indicated an interchange between the Gulf of Guayaquil and the 14 Fathom Bank off Peru (Figure 7b).

Discussion

From the Baja California tag returns we infer that yellowfin tuna move north along the coast of Baja California during May, June and July. During the latter month some start to move south, and southerly movements continue through September and October. Also there is an

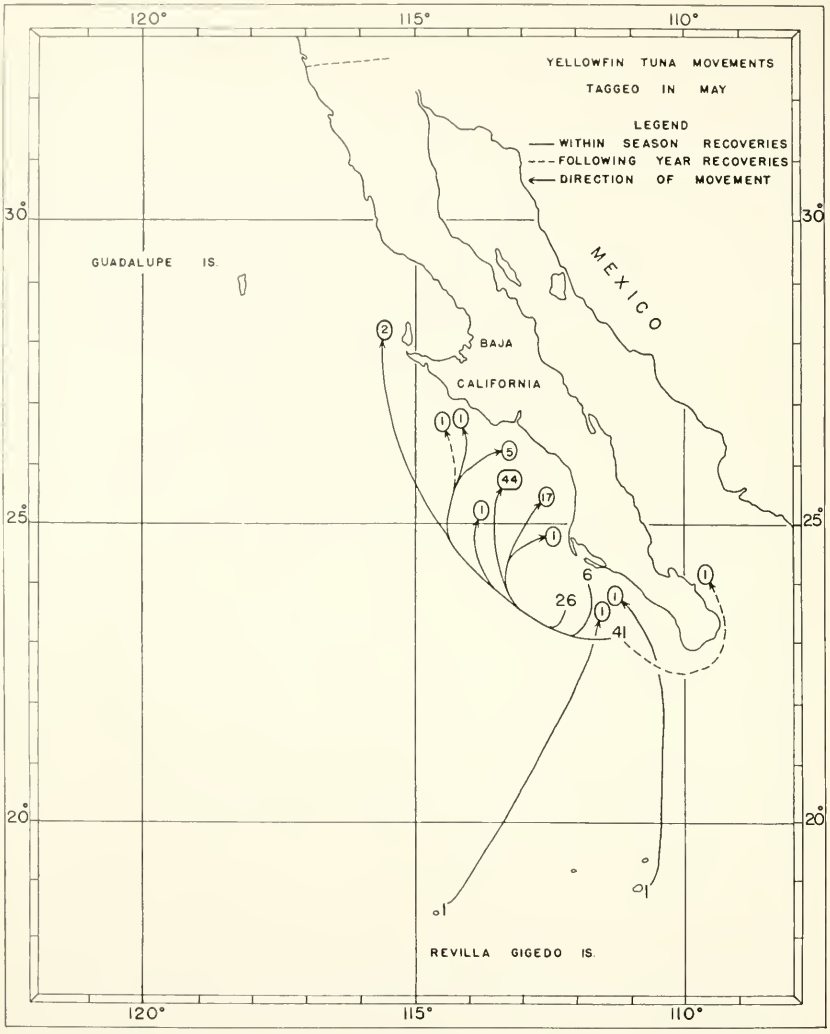

FIGURE 5a. Yellowfin tuna movements of 75 or more miles as shown by recoveries of fish tagged in 1958. Uncircled figures represent origins of the tagged fish.

interchange of yellowfin between Baja California and the Revilla Gigedo Islands. Further the seasonal fisheries off Baja California, the Gulf of California, and the Revilla Gigedo Islands are supported in some degree by the northerly movements of yellowfin tuna along the Mexican coast in winter and spring from at least as far south as the Gulf of Tehuantepec. Recoveries of two fish tagged off Central America that crossed the Gulf of Tehuantepec to central Mexico bring out the

possibility that in some years fish from Central America may move into these fishing areas.

Recoveries at various localities of four yellowfin, tagged in February within a few miles of each other near the Gulf of Tehuantepec, may indicate that the schools into which they were released first entered the Gulf of California around May, moved to the Baja California fishing grounds by August and then traveled to the Revilla Gigedo Islands in October and November (Figure 6a).

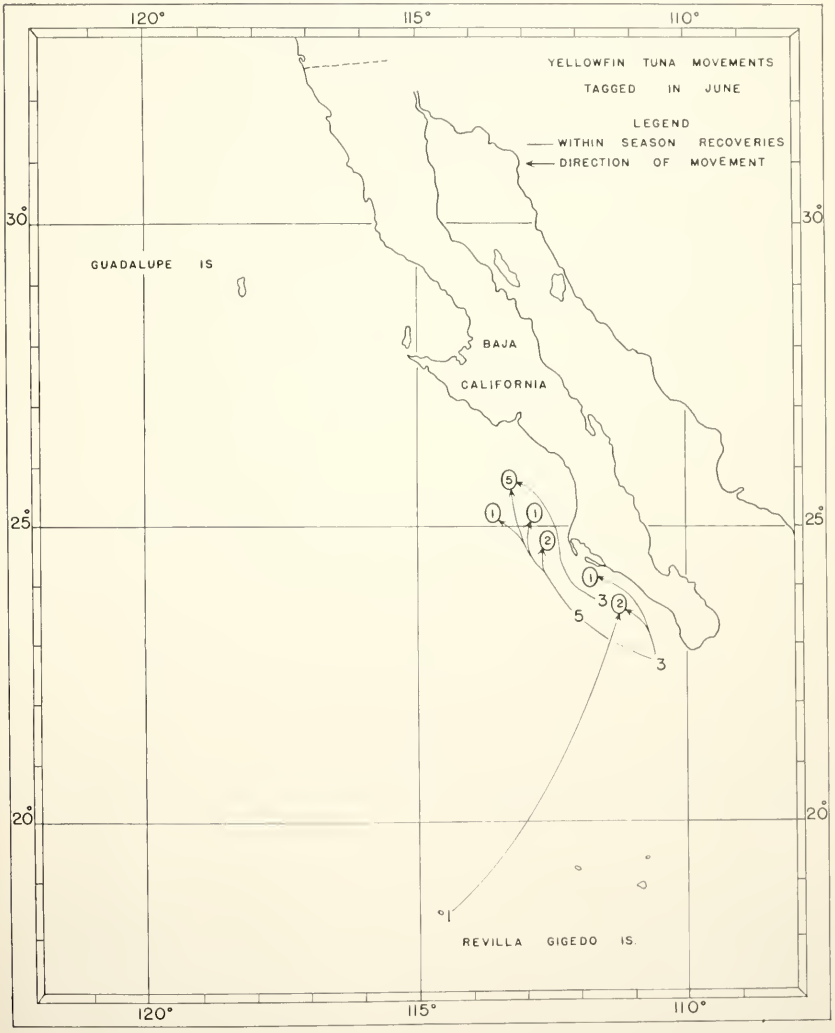

FIGURE 5b. Yellowfin tuna movements of 75 or more miles as shown by recoveries of fish tagged in 1953 and 1958. Uncircled figures represent origins of the tagged fish.

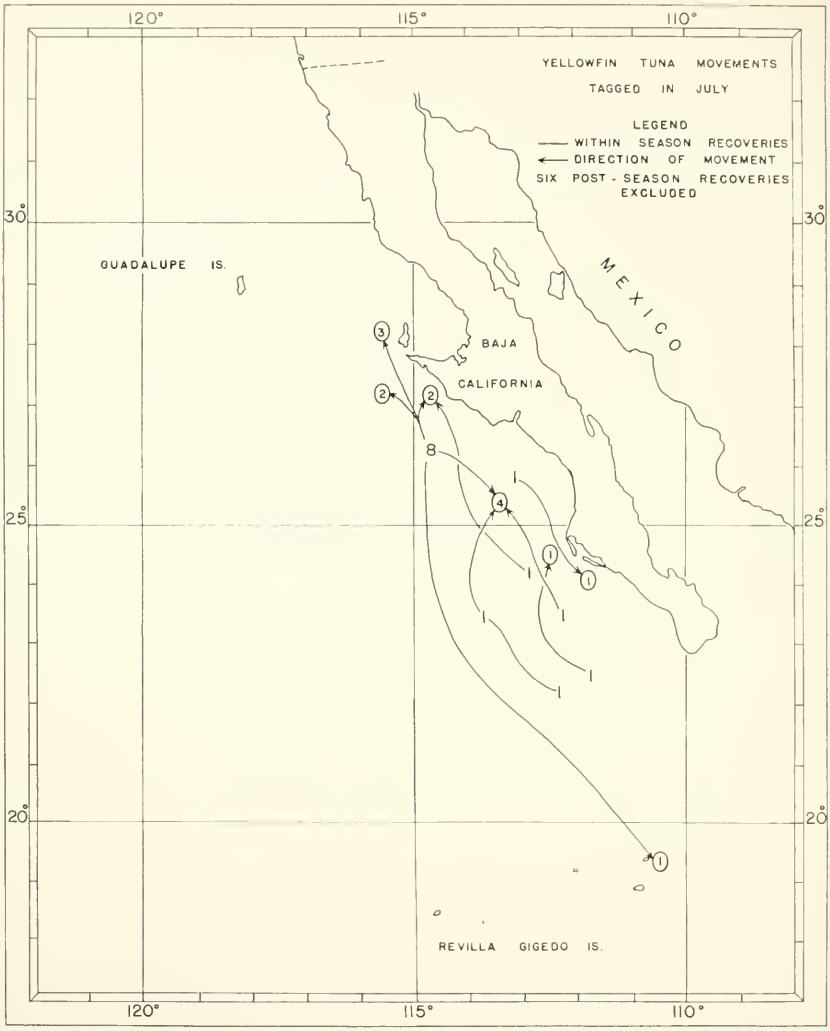

FIGURE 5c. Yellowfin tuna movements of 75 or more miles as shown by recoveries of fish tagged in 1953, 1956, and 1958. Uncircled figures represent origins of the tagged fish.

The Baja California fishery is exploited effectively by purse seiners and baitboats during late spring, summer and fall and substantial tonnages are caught. When the fishery fails, generally by winter, the area or areas to which these fish disseminate are in question. Since there were no recoveries of Baja California tagged fish along the Mexican coast it appears there was little or no movement in that direction. Tag returns did indicate some dissemination of fish from Baja California to the Gulf of California.

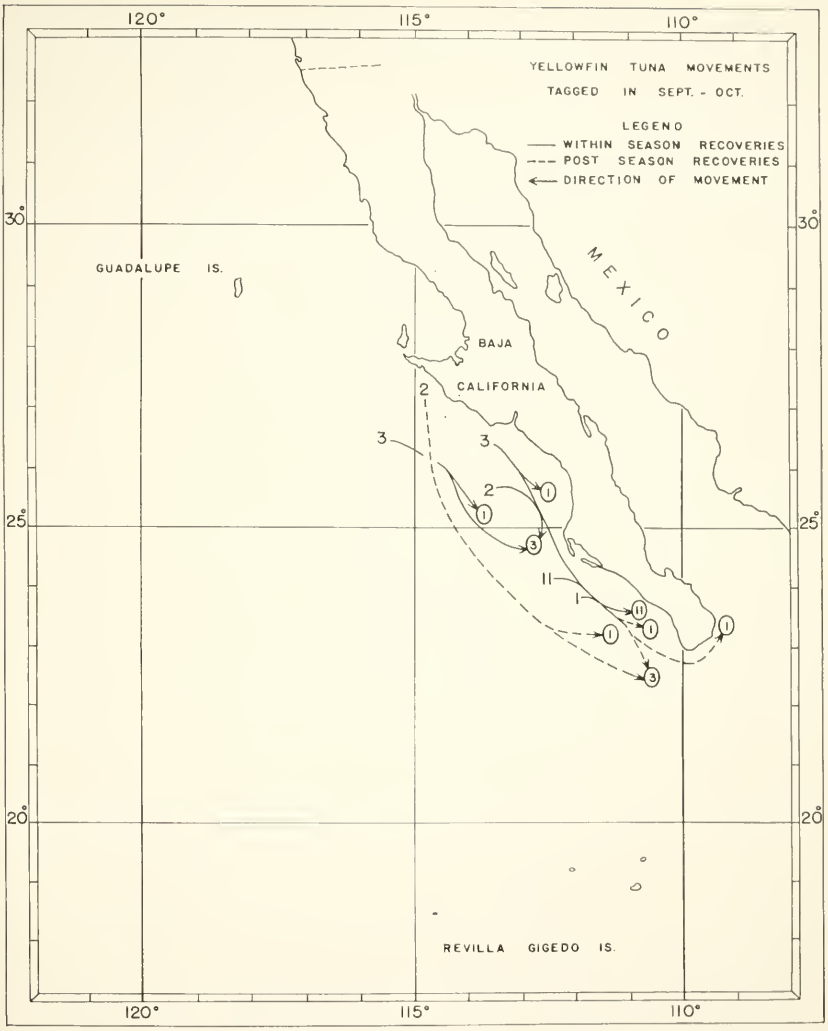

FIGURE 5d. Yellowfin tuna movements of 75 or more miles as shown by recoveries of fish tagged in 1952 and 1955. Uncircled figures represent origins of the togged fish.

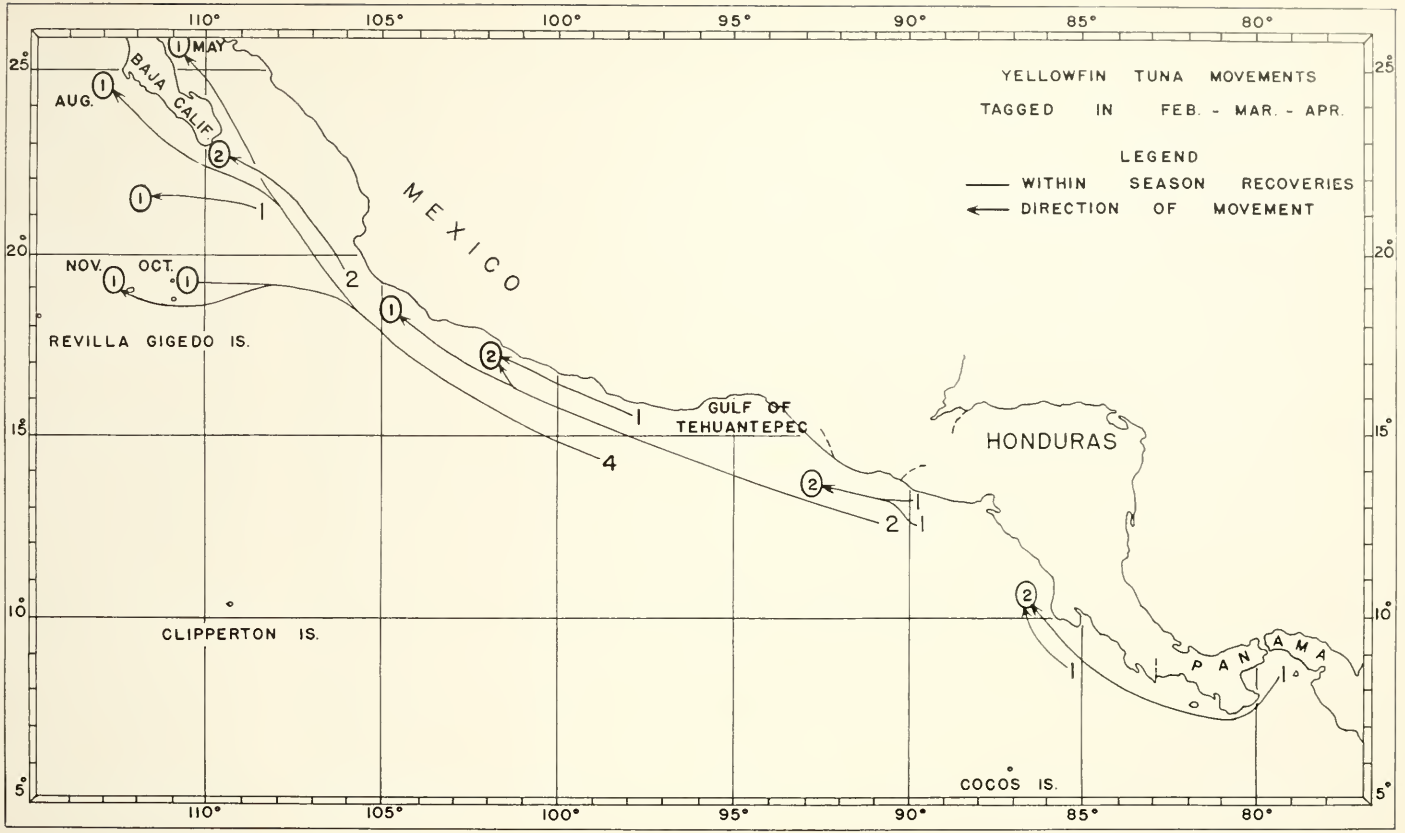

FIGURE 6a. Yellowfin tuna movements of 75 or more miles as shown by recoveries of fish tagged in 1952, 1954, 1955, and 1957. Uncircled figures represent origins of the tagged fish.

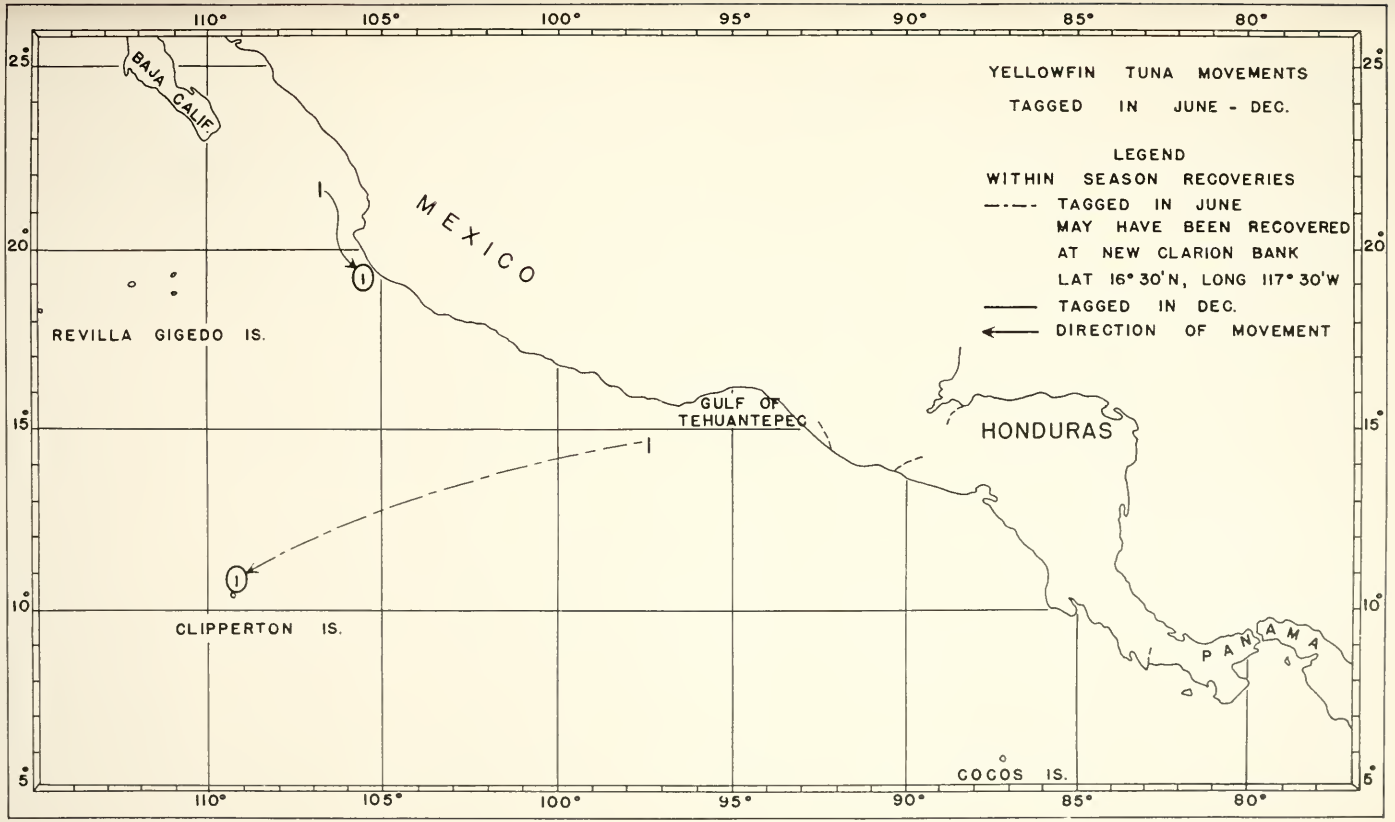

FIGURE 6b. Yellowfin tuna movements of 75 or more miles as shown by recoveries of fish tagged in 1956 and 1957. Uncircled figures represent origins of the tagged fish.

Substantial numbers of recoveries of fish tagged off Baja California have been made the following season (Table 7), many within 90 miles of the point of tagging. One tuna tagged in July 1956 was recaptured 842 days later only 87 miles from its release point. The small number of off-season recoveries reflects their virtual disappearance during that period of the year. This suggests the possibility that Baja California tuna migrate to areas not subjected to fishing at that time of year.

TABLE 7

Season of Recapture for 167 Yellowfin Tuna Tagged, May to December, Off Baja California, 1952-1958

Within-season (May to Dec.)	Off-season (Jan. to Apr.)	Within-season (One year later)	Within-season (Two years later)
150	4	12	1

Fish tagged off the Gulf of Guayaquil and Peru did not move from these areas into Central America (Figure 7a, b). Movement between the Galapagos Islands and the Gulf of Guayaquil does take place as evidenced by one recovery. Recoveries made along the coast of Peru indicate that there is some movement between the Gulf of Guayaquil and the 14-Fathom Bank throughout the year.

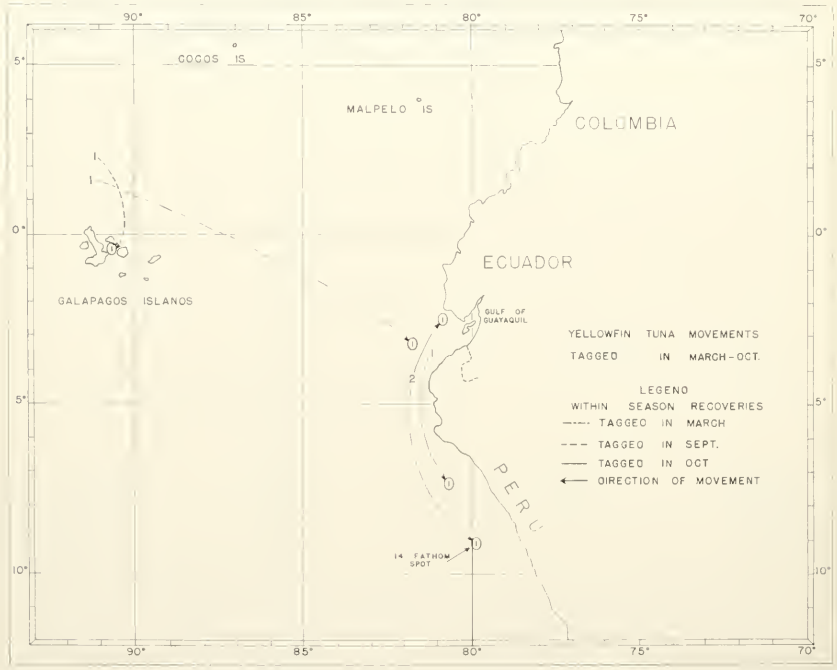

FIGURE 7a. Yellowfin tuna movements of 75 or more miles as shown by recoveries of fish tagged in 1954 and 1958. Uncircled figures represent origins of the tagged fish.

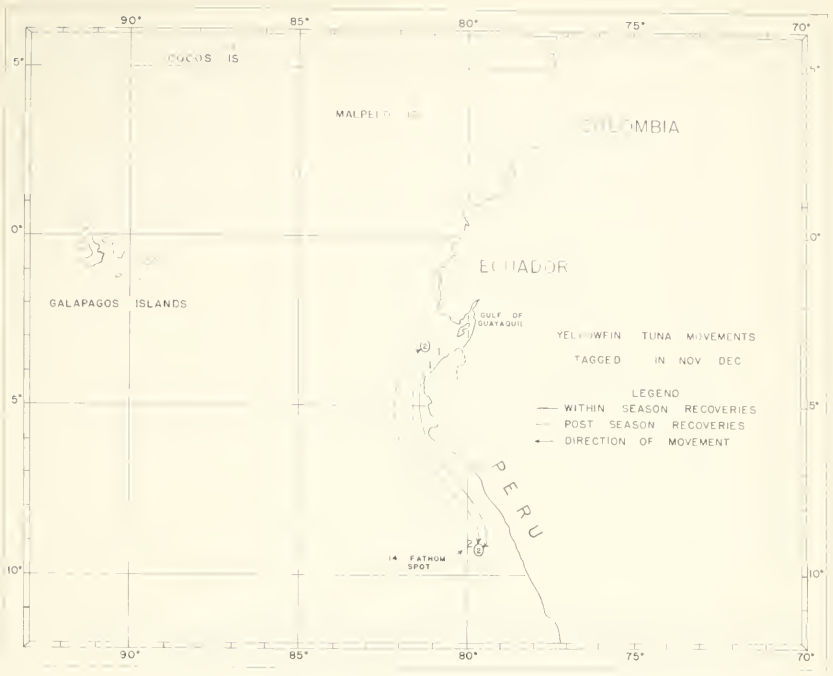

FIGURE 7b. Yellowfin tuna movements of 75 or more miles as shown by recoveries of fish tagged in 1952 and 1958. Uncircled figures represent origins of the tagged fish.

Tagging mortality and nonobservation of tags during normal handling and processing of the tunas have, without doubt, materially affected the recovery rates. Even so recoveries of tagged yellowfin tuna from 1954 to 1959 indicate a rate of harvest which in most areas would not be expected to have an appreciable effect upon the population (Table 8). Exceptions might be the Baja California and Peruvian fisheries.

TABLE 8

Recovery Rates of Yellowfin Tuna Tagged in Ten Fishing Areas, May, 1954 to May, 1959

Fishing area	No. tagged	No. recovered	Percent returned
Baja California	1,845	150	8.1
Revilla Gigedo Islands	421	7	1.7
Coast of Mexico	2,321	8	0.3
Central America	2,412	6	0.2
Clipperton Island	54	0	0
Cocos Island	76	0	0
Galapagos Islands	330	1	0.3
Ecuador-Columbia	51	0	0
Guayaquil-Peru	1,078	48	4.5
Chile	70	0	0

Shimada and Schaefer (1956) studied the relationship between population abundance and fishing intensity in the eastern Pacific for the years 1934 to 1953. They concluded that fishing has had a real effect upon the stock of eastern Pacific yellowfin tuna, taken in the aggregate, over the period studied.

Rather large differences in recovery rates exist between the center of the fishing range off Mexico, Central America, Ecuador-Colombia and areas near the northern and southern extremes off Baja California and Guayaquil-Peru. Tag recoveries from Baja California and Peru-

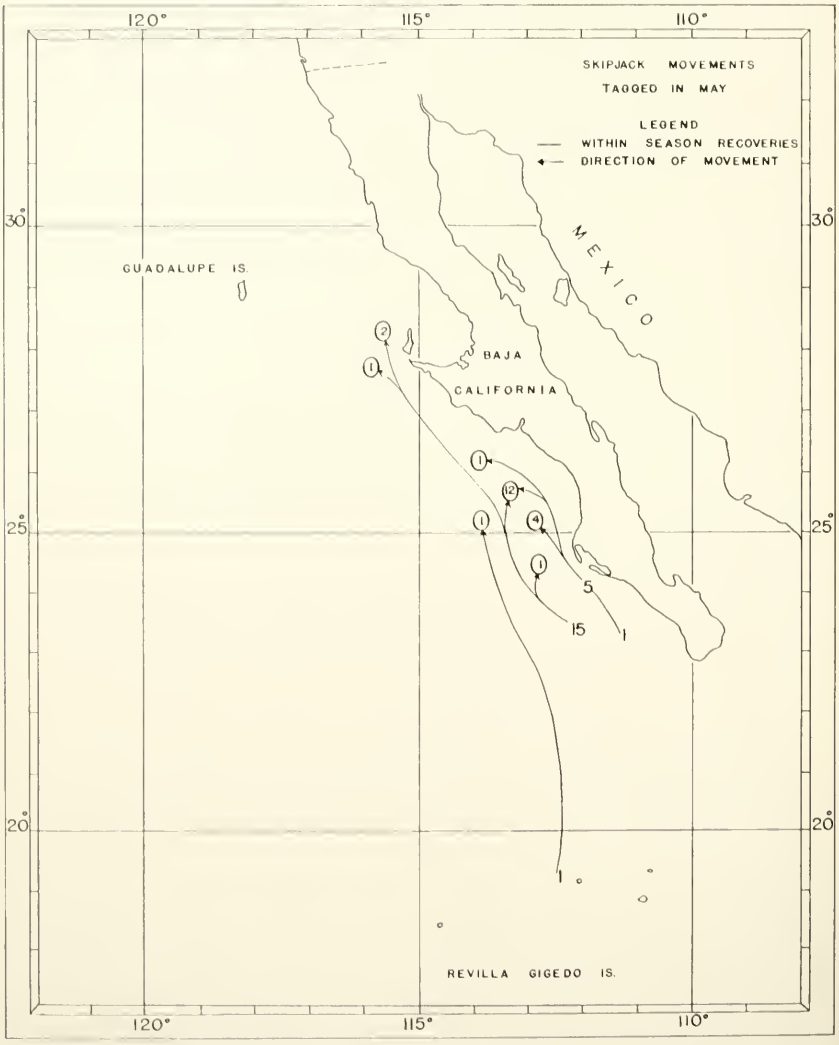

FIGURE 8a. Skipjack movements of 75 or more miles as shown by recoveries of fish tagged in 1958. Uncircled figures represent origins of the tagged fish.

Guayaquil were 8.1 and 4.5 percent respectively. Tagging in the central areas of the fishery yielded between 0.2 and 0.3 percent.

The reasons for these differences, which are considerably more divergent than would be expected, are not readily apparent.

Recoveries of Tagged Skipjack

Through November 30, 1959, 237 of 14,265 tagged skipjack had been received. They had been at liberty from one to 271 days and demonstrated straight line movements of up to 720 miles. Those having moved 75 or more miles were selected for graphic presentation (Figures 8, 9, and 10). Detailed information for every recovery can be found in the Appendices.

Baja California and the Revilla Gigedo Islands movements (Figures 8a, 8b, 8c, 8d) were by fish that had been at liberty from 8 to 139 days and traveled 80 to 410 miles. Fish tagged in these areas in May (Figure 8a) generally moved upcoast, one going from Roca Partida, Revilla Gigedo Islands, to Baja California. This northerly movement was also demonstrated by some of the June tagging returns (Figure 8b). Returns from July tagging (Figure 8c) demonstrated a predominant northerly movement, extending to the California-Mexico border; however, one-third were recovered south of the tagging point. All recoveries from September tagging showed a southerly movement (Figure 8d).

Only three returns were received from tagging off Mexico and Central America (Figure 9), two of which had moved more than 75 miles. Both were recovered north of the point of tagging.

Movements shown in Figures 10a, b, and c for Ecuador and Peru were from fish that had been at liberty from 16 to 192 days, and had moved 75 to 120 miles. April tagging returns from this area (Figure 10a) demonstrated northerly movement from the 14-Fathom Bank to the Gulf of Guayaquil and Ecuador. September and October tagging (Figure 10b) showed an interchange of fish between the 14-Fathom Bank and the Gulf of Guayaquil, with one fish moving from the Gulf of Guayaquil to an area north of the Galapagos Islands. November, December and January tagging returns (Figure 10c) showed several movements to the Gulf of Guayaquil from the 14-Fathom Bank, and one to the 14-Fathom Bank from the Gulf of Guayaquil.

Discussion

Returns from tagging off Baja California indicate a northerly movement in May and June (Figure 8a, b); a transitional period with movements both north and south during July (Figure 8c) and an entirely southerly movement in September (Figure 8d). Movement between the Revilla Gigedo Islands and Baja California was evidenced by a single recovery off Baja California.

Returns from tagging off Ecuador and Peru revealed a general interchange of fish between the 14-Fathom Bank and the Gulf of Guayaquil (Figures 10b, c). Returns from tagging during April (Figure 10a) demonstrated a movement from the 14-Fathom Bank to the Gulf of Guayaquil.

A skipjack tagged in October near the Gulf of Guayaquil and recovered 45 days later north of the Galapagos Islands indicated a movement between the mainland and the Galapagos Islands.

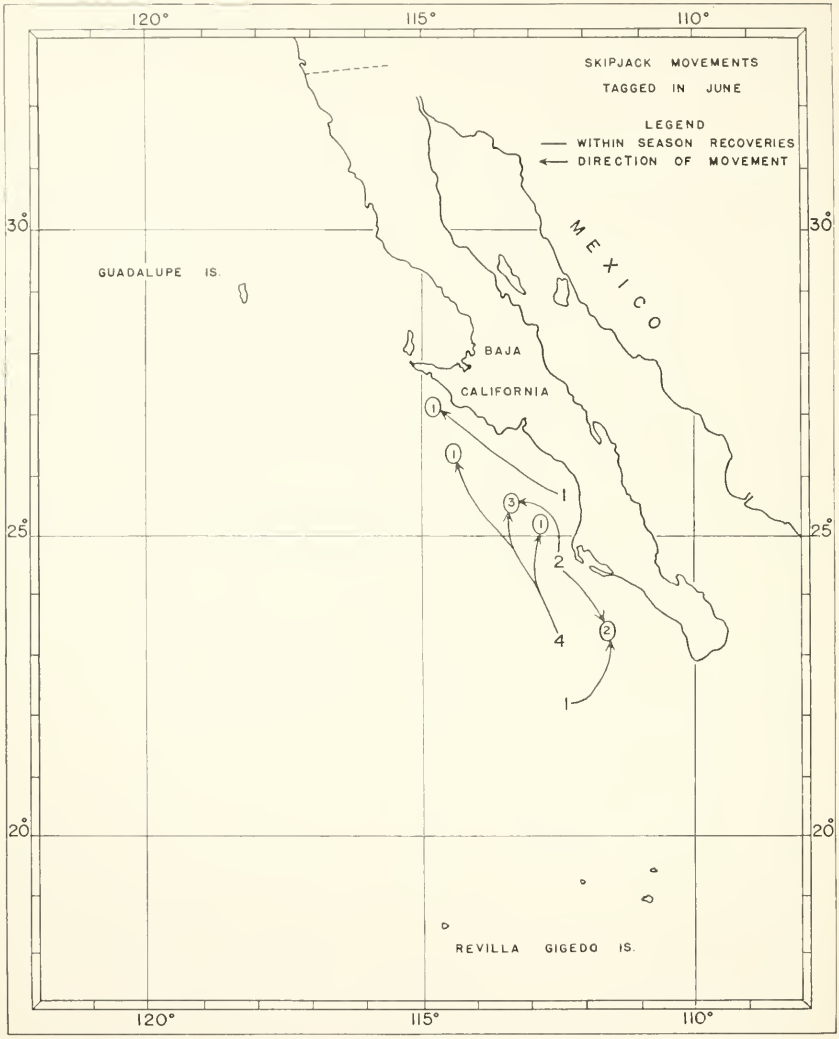

FIGURE 8b. Skipjack movements of 75 or more miles as shown by recoveries of fish tagged in 1953 and 1958. Uncircled figures represent origins of the tagged fish.

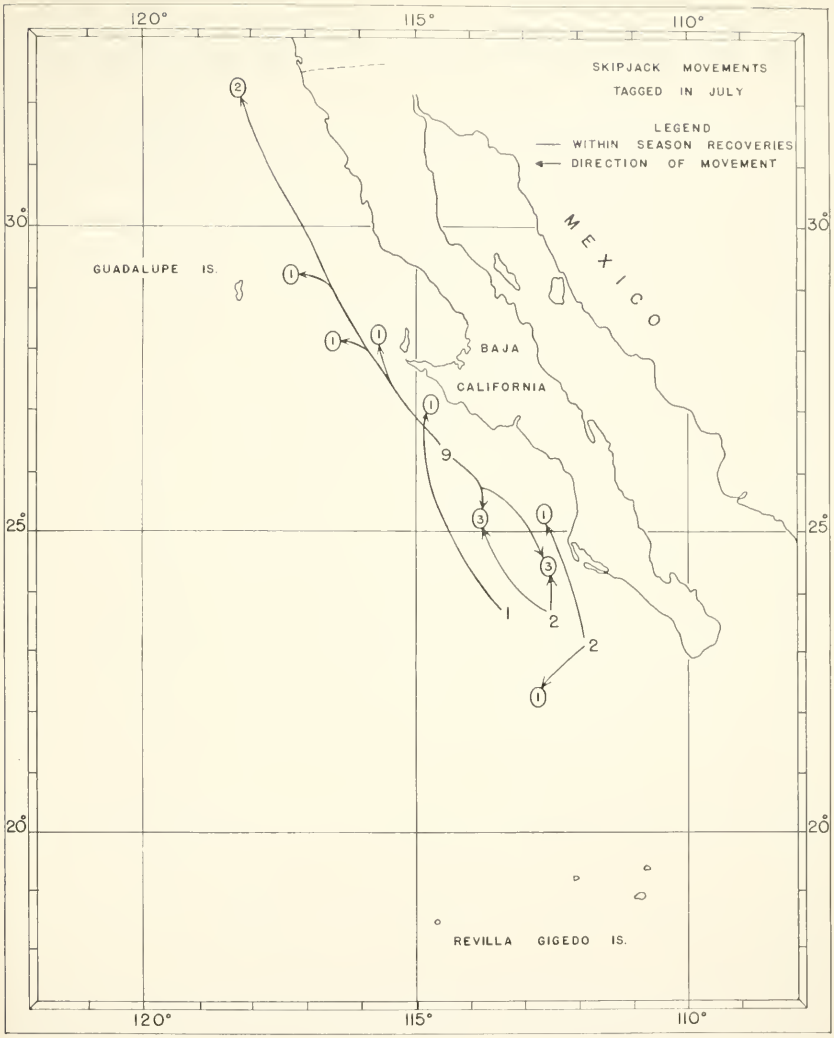

FIGURE 8c. Skipjack movements of 75 or more miles as shown by recoveries of fish tagged in 1953, 1956, and 1958. Uncircled figures represent origins of the tagged fish.

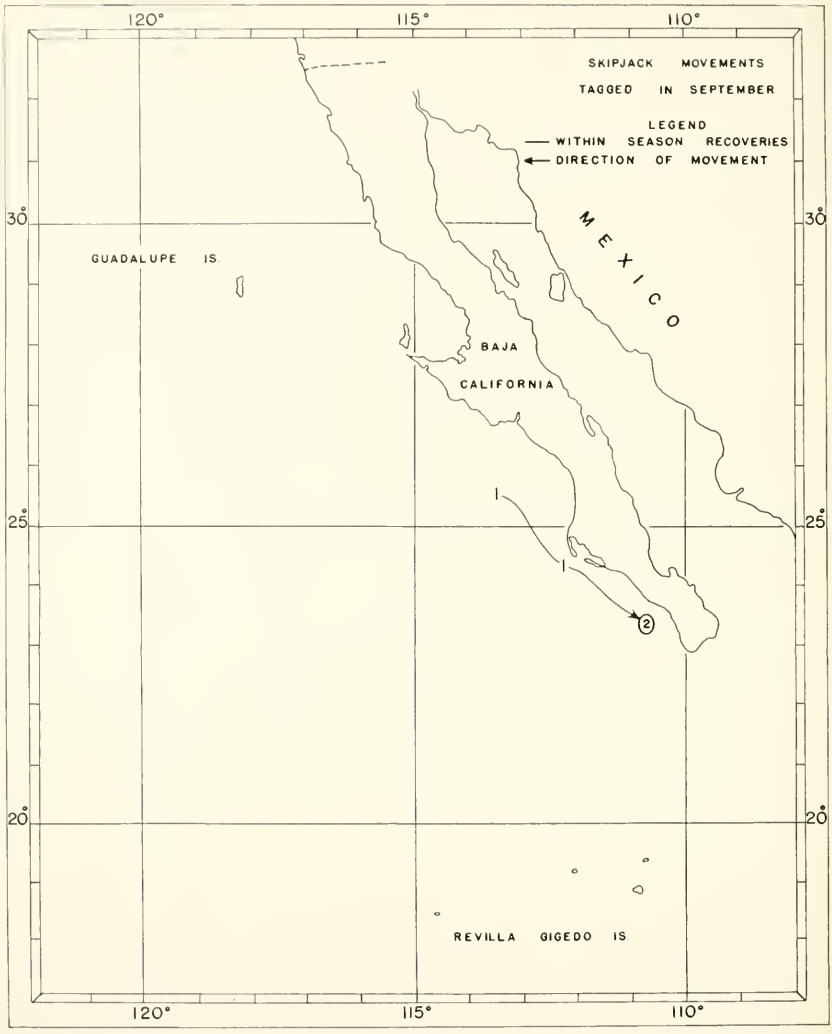

FIGURE 8d. Skipjack movements of 75 or more miles as shown by recoveries of fish tagged in 1955. Uncircled figures represent origins of the tagged fish.

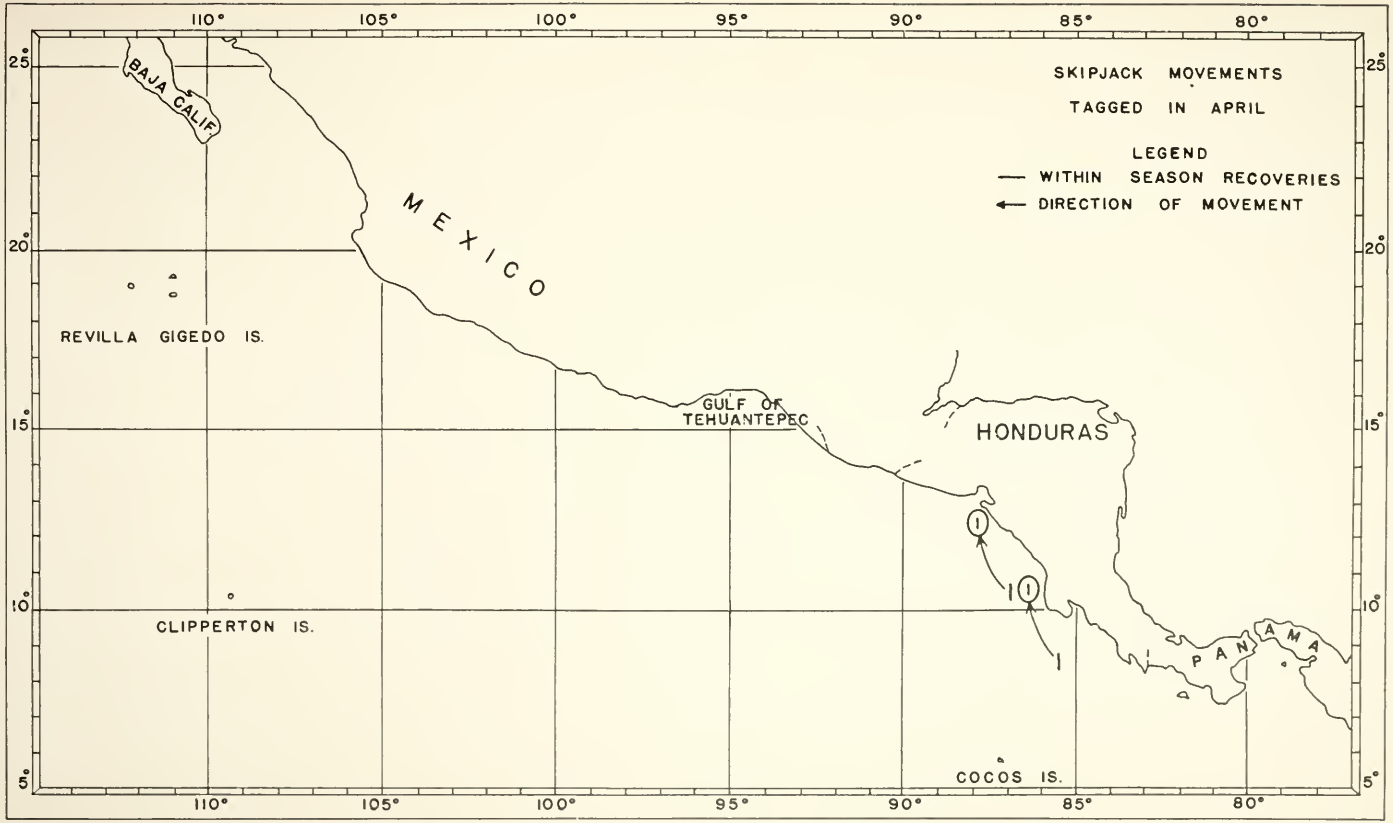

FIGURE 9. Skipjack movements of 75 or more miles as shown by recoveries of fish tagged in 1954. Uncircled figures represent origins of the tagged fish.

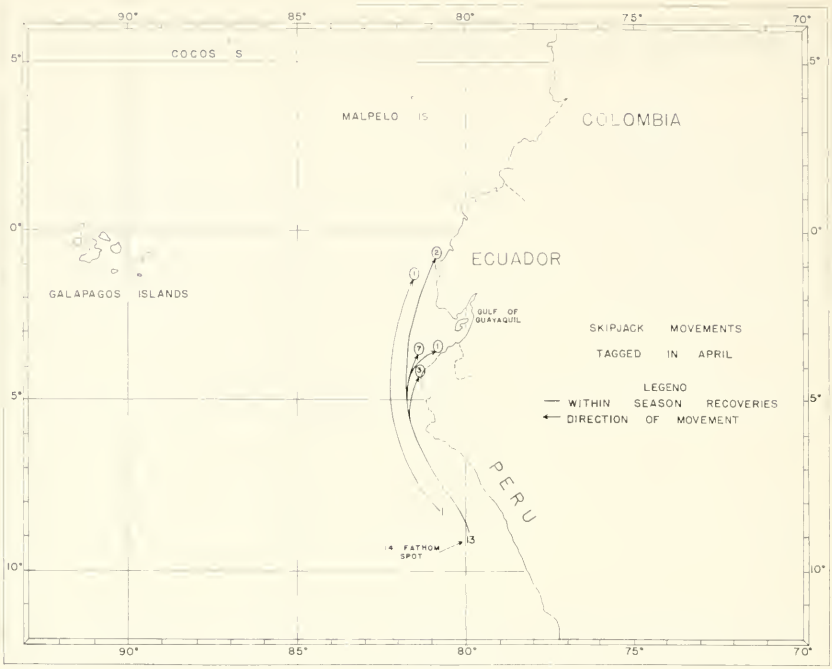

FIGURE 10a. Skipjack movements of 75 or more miles as shown by recoveries of fish tagged in 1959. Uncircled figures represent origins of the tagged fish.

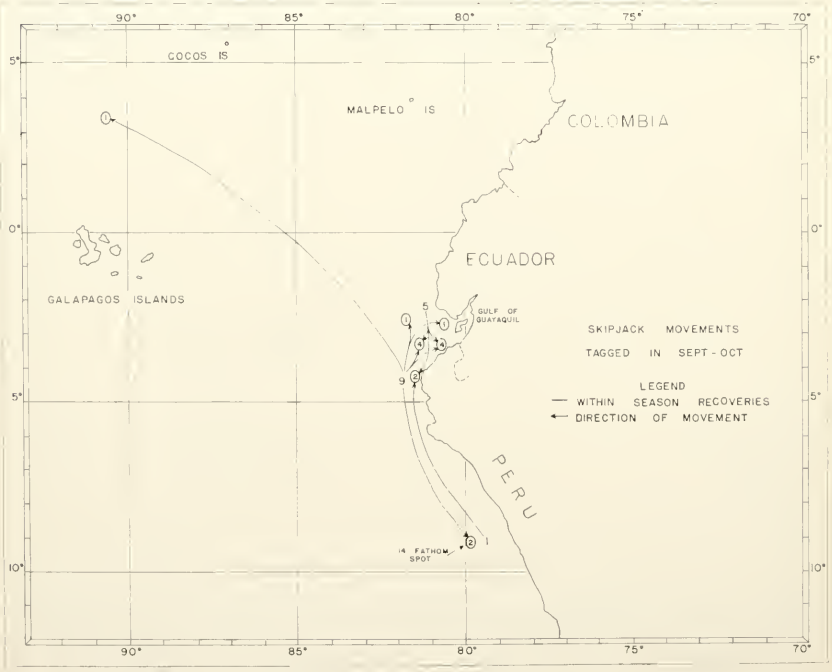

FIGURE 10b. Skipjack movements of 75 or more miles as shown by recoveries of fish tagged in 1958. Uncircled figures represent origins of the tagged fish.

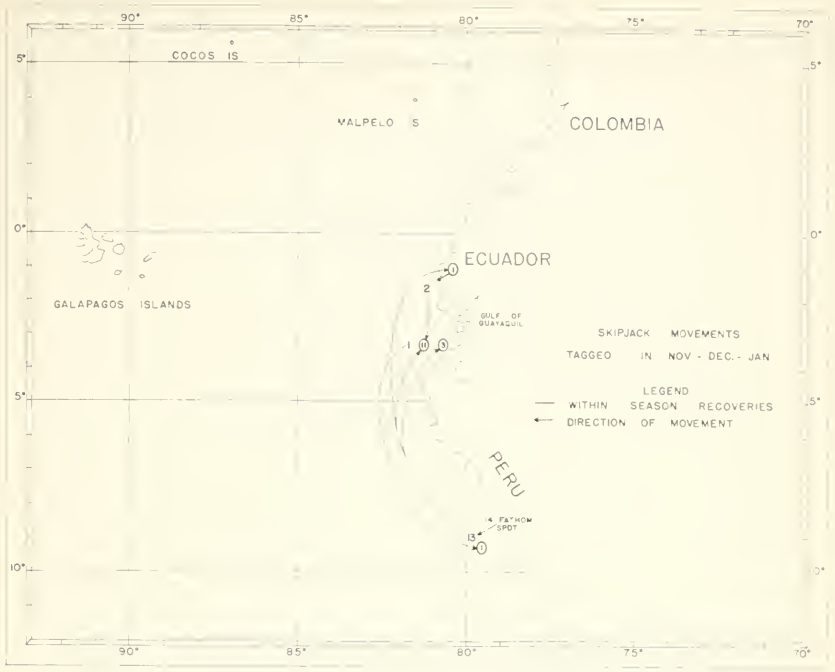

FIGURE 10c. Skipjack movements of 75 or more miles as shown by recoveries of fish tagged in 1957 and 1958. Uncircled figures represent origins of the tagged fish.

YELLOWFIN TUNA GROWTH

A second objective of our tagging program was to estimate the growth of yellowfin tuna. Many fishermen removed the tags and sent them in by mail. This prevented our obtaining complete recovery data on all 263 tags returned to us. Regardless, we did get complete data on 124 yellowfin tuna tagged off Baja California and the Revilla Gigedo Islands, 14 tagged off Mexico and Central America, 19 tagged off Peru, and 5 from other areas. These fish, 440 to 990 mm. fork length at time of tagging were at liberty for one to 842 days. Detailed information of individual tag recoveries is tabulated in Appendix B.

Baja California-Revilla Gigedo Island area data indicate that average one-year growth rates for similar sized yellowfin tuna were not the same for each year of tagging. At time of tagging, size ranges of the fish used for growth analyses were 440 to 650 mm. for 1953 tagging, 585 to 645 mm. for 1955, and 500 to 750 mm. for tagging during 1958 (Table 9). One-year growth rates were 200 mm., 420 mm., and 350 mm. for 1953, 1955 and 1958 respectively. Data from the remaining areas of tagging are not sufficient for annual growth rate determination.

TABLE 9

Growth Statistics for 112 Yellowfin Tuna From the Baja California-Revilla Gigedo Island Area

Year of tagging	Number of individuals	Length (mm.)		Days at liberty	Statistics of the regression lines				
		Range	Mean	Range	Mean X	Mean increment Y	Intercept a	Slope b	Standard error
1953	15	440–650	536.3	1–367	120.87	63.40	—4.16	0.56	20.31
1955	14	585–645	615.4	21–295	100.00	61.36	—53.53	1.15	19.59
1958	83	500–750	611.7	3–233	59.77	35.49	—21.80	0.96	24.17

Data used for growth analyses of yellowfin tuna of the Baja California-Revilla Gigedo Island area were from recoveries, through November 30, 1959, of fish tagged during 1953, 1955 and 1958. They were from fish that had been at liberty from one to 367 days (Table 9). The change in length of each fish was plotted against days at liberty. For each year, a straight line was fitted by least squares (Figure 11).

Regression analysis, using the method of Ostle (1954), of the growth data was undertaken to determine if there was a significant difference between the growth rates for 1953, 1955 and 1958. These tests showed a significant difference ($F = 14.07$; $F_{.01\ (4,\ 100)} = 3.98$) among the regressions and further showed significant differences ($F = 270.50$; $F_{.01\ (2,\ 100)} = 4.82$) among their slopes. We conclude then that yellowfin tuna tagged in the Baja California-Revilla Gigedo Island area during 1953, 1955 and 1958 did not exhibit similar growth characteristics, and should therefore be treated separately.

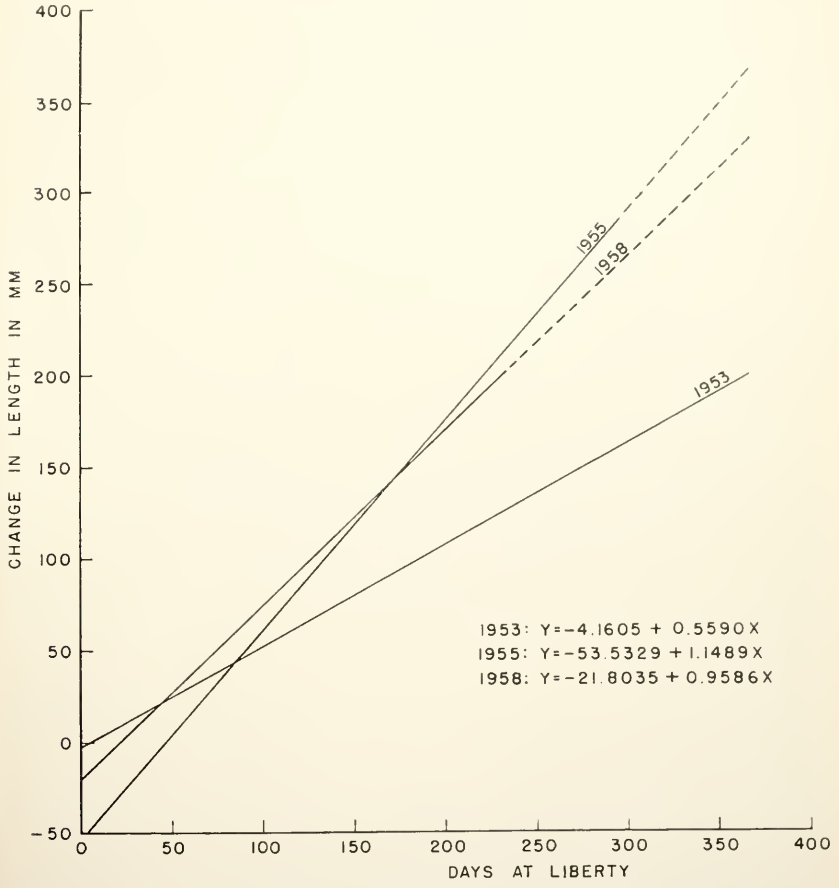

FIGURE 11. Yellowfin tuna growth for the Baja California-Revilla Gigedo Island Area during the years 1953, 1955, and 1958.

Inspection of the growth curves reveals an apparent body length shrinkage graphically illustrated where the growth lines intersect the ordinate. Exact values for these intercepts are —4.16 for 1953 tagging, —53.53 for 1955, and —21.80 for 1958 (Table 9). The many variables involved in measuring fish at sea and ashore and in body length shrinkage brought about by freezing are the main causes of this apparent negative increment. Loss in body length due to freezing has been demonstrated by Godsil and Greenhood (1951). They found that 54 Hawaiian yellowfin tuna, averaging 615 mm. in body length, lost an average 8.28 mm. when frozen for four to five weeks. This loss was slightly less than determined in subsequent work by the authors.

Our one-year growth rates determined from 1955 and 1958 tagging, in the Baja California-Revilla Gigedo Island area, are much the same as noted by Moore (1951) from modal progression of length frequencies of Hawaiian tuna caught during 1948 and 1949; and by Schaefer (1959) from temporal progression of size classes of Mexican yellowfin tuna caught during 1955 and 1956.

Data from our 1953 tagging reveal much slower growth than for the other two years investigated. This difference probably is valid, since the data agree with modal progression of length frequencies from that area.

SUMMARY

1. The California tuna industry is the most important fishery industry in the State. Yellowfin tuna and skipjack compose a single fishery extending from California to Chile. Because of the value of the fishery to the economy of the State, the Department of Fish and Game has gathered data pertinent to its management.

2. It was felt that tagging offered the most direct method of defining the tuna stocks that support the eastern Pacific fishery. The first successful tuna tag was developed in 1952 by investigations of the California Department of Fish and Game. Wilson (1953) reported on results of initial field trials. These trials demonstrated that yellowfin tuna and skipjack would survive tagging, and the tags would remain in place with no apparent effects on the fish.

3. Three vinylite tubing tags, Types E, F, and G, looped through the flesh immediately behind the second dorsal fin were tested during a field trial from October, 1952 to April, 1954. During this time, 4,204 yellowfin tuna and 2,839 skipjack were tagged. Based on recovery rates, the Type G tag was selected as the best.

4. With the marketing of an improved ink the protective outer jacket of the Type G "spaghetti" tag was removed in 1956. An improved yellow vinylite, Resinite X-270-I, was used in the construction of all tags starting with 1957.

5. Dart tags were field tested against the Type G tag in 1959. Skipjack returns were in favor of the dart tag.

6. From 1952 through 1959, 13,213 yellowfin tuna and 14,265 skipjack were tagged in the eastern Pacific. Of these, 263 yellowfin and 237 skipjack were recovered.

7. Yellowfin tuna and skipjack recovered 75 or more miles from point of tagging were used in demonstrating migrations by months of the year.

8. Both yellowfin tuna and skipjack moved north along the coast of Baja California during May, June, and July. By July some fish had started to move south and southerly movements continued through September and October.

9. There was an apparent interchange of yellowfin tuna between the Revilla Gigedo Islands and Baja California. For skipjack, however, the movement was one way—from the Revilla Gigedo Islands to Baja California.

10. Tag returns indicated the fisheries off Baja California, the Gulf of California and the Revilla Gigedo Islands are supported, in some degree, by yellowfin tuna moving north along the Mexican coast in winter and spring from at least as far south as the Gulf of Tehuantepec, and probably from as far south as Central America. This was not found to be true, however, for skipjack.

11. Yellowfin tuna and skipjack did not move between the Central American fishery and those off Peru and the Galapagos Islands. However, yellowfin tuna moved from the Galapagos Islands to Peru and skipjack moved from Peru to the islands.

12. Yellowfin tuna and skipjack traveled between the Gulf of Guayaquil and the 14-Fathom Bank.

13. The Baja California-Revilla Gigedo Island area data were sufficient for annual growth rate estimation. Based on tagging, one-year growth rates for yellowfin tuna 440 to 750 mm. body length were 200 mm., 420 mm. and 350 mm. for 1953, 1955 and 1958 respectively.

ACKNOWLEDGMENTS

Investigations of this type require the whole hearted efforts of many people. Mr. Robert C. Wilson instigated the program in 1952 and the first tags were developed by Mr. Edward C. Greenhood and Mr. Harold B. Clemens. Since that time the program has been under the direction of a number of people and each contributed materially. The early experimental work was conducted aboard the research vessel *N. B. SCOFIELD* and sincere thanks are due Captain Ivo Kuselj and his crew.

The lion's share of the actual tagging fell upon Fish and Game Assistants who spent long and arduous hours at sea. Appreciation is also extended to the skippers and fishermen of the tuna clippers who were most co-operative in allowing us to accompany them to sea. Special thanks are due Captain Lou Brito and the crew of the tuna clipper *SOUTHERN PACIFIC* (now a purse seiner) who were especially co-operative during six different tagging trips aboard their vessel.

We wish to acknowledge the advice and counsel given by Mr. Norman Abramson in the statistical computations of the growth section. Miss Judith Cohen drew the charts and figures and special thanks are due her.

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APPENDIX

APPENDIX A

Release and Recovery Data for 263 Pacific Yellowfin Tuna Tags Returned, 1952 Through 1958

Release					Recovery					
Date	Latitude	Longitude	Length (mm.)	Surface temperature (degrees F.)	Latitude	Longitude	Days at liberty	Increment (mm.)	Distance traveled (miles)	Recovery gear*
1952	**Baja California**									
Oct. 11	27° 10′ N.	114° 40′ W.	610	--	22° 32′ N.	110° 43′ W.	254	58	351	PS
Oct. 12	27° 05′ N.	114° 38′ W.	630	--	23° 18′ N.	111° 46′ W.	260	160	278	BB
Oct. 20	26° 30′ N.	113° 50′ W.	540	--	25° 13′ N.	112° 37′ W.	35	—1	102	BB
Oct. 20	26° 30′ N.	113° 50′ W.	550	--	22° 53′ N.	110° 14′ W.	204	125	292	PS
Oct. 20	26° 30′ N.	113° 50′ W.	570	--	25° 33′ N.	113° 13′ W.	29	—6	67	BB
Oct. 20	26° 30′ N.	113° 50′ W.	600	--	24° 13′ N.	112° 02′ W.	38	--	115	BB
Oct. 21	26° 24′ N.	115° 53′ W.	555	--	24° 32′ N.	112° 19′ W.	30	--	220	BB
Oct. 21	26° 24′ N.	115° 53′ W.	580	--	25° 45′ N.	113° 25′ W.	61	—14	133	BB
Oct. 21	26° 24′ N.	115° 53′ W.	600	--	24° 16′ N.	112° 02′ W.	39	22	250	BB
1953										
June 23	22° 50′ N.	111° 45′ W.	525	73	--	--	1	--	--	PS
June 25	22° 40′ N.	110° 45′ W.	560	71	--	--	--	—18	--	BB
June 28	22° 40′ N.	110° 48′ W.	560	71	24° 04′ N.	111° 24′ W.	39	17	98	PS
June 28	22° 40′ N.	110° 48′ W.	650	71	24° 48′ N.	112° 35′ W.	41	—10	165	BB
June 28	22° 40′ N.	110° 45′ W.	530	70	23° 32′ N.	111° 53′ W.	12	--	81	PS
June 30	23° 11′ N.	111° 40′ W.	555	--	23° 49′ N.	111° 15′ W.	36	7	45	PS
July 2	22° 26′ N.	111° 21′ W.	520	--	23° 36′ N.	111° 42′ W.	363	199	74	PS
July 2	22° 26′ N.	111° 21′ W.	540	--	24° 43′ N.	112° 34′ W.	58	30	155	BB
July 3	22° 21′ N.	111° 29′ W.	560	--	22° 29′ N.	111° 30′ W.	1	—11	8	PS
July 5	23° 18′ N.	112° 14′ W.	490	--	26° 30′ N.	114° 32′ W.	373	--	230	PS
July 9	23° 42′ N.	112° 27′ W.	510	--	23° 41′ N.	111° 46′ W.	6	--	38	PS
July 10	23° 37′ N.	112° 32′ W.	530	--	25° 40′ N.	113° 18′ W.	17	--	130	PS
July 11	22° 34′ N.	113° 13′ W.	495	--	26° 20′ N.	114° 38′ W.	367	210	242	PS
July 15	23° 47′ N.	112° 25′ W.	505	--	21° 31′ N.	110° 58′ W.	344	180	212	PS
July 21	23° 45′ N.	112° 00′ W.	490	--	23° 05′ N.	111° 52′ W.	3	3	40	PS
July 24	22° 21′ N.	112° 34′ W.	440	--	25° 44′ N.	113° 11′ W.	110	76	206	BB
July 24	25° 33′ N.	113° 23′ W.	545	--	24° 04′ N.	111° 24′ W.	12	—5	139	PS
July 24	25° 33′ N.	113° 23′ W.	600	--	25° 35′ N.	113° 25′ W.	4	—5	2	PS
July 24	25° 33′ N.	113° 23′ W.	765	--	25° 18′ N.	113° 02′ W.	27	--	22	PS
July 25	23° 34′ N.	113° 10′ W.	515	--	23° 29′ N.	111° 09′ W.	283	129	110	BB
July 28	23° 41′ N.	113° 00′ W.	510	--	25° 44′ N.	113° 11′ W.	107	112	124	BB

1954										
July 20	23° 27′ N.	111° 30′ W.	--	--	23° 42′ N.	111° 38′ W.	4	--	16	BB
1955										
Sep. 12	25° 30′ N.	113° 25′ W.	585	75.9	23° 33′ N.	110° 31′ W.	92	30	194	BB
Sep. 12	25° 30′ N.	113° 25′ W.	595	75.9	23° 35′ N.	110° 47′ W.	111	67	187	BB
Sep. 13	23° 50′ N.	111° 50′ W.	590	79.9	23° 30′ N.	111° 40′ W.	42	—2	23	BB
Sep. 13	23° 50′ N.	111° 50′ W.	615	79.9	23° 19′ N.	110° 38′ W.	117	71	80	BB
Sep. 14	23° 50′ N.	111° 50′ W.	640	80.1	23° 35′ N.	110° 47′ W.	85	71	58	BB
Sep. 15	24° 20′ N.	112° 00′ W.	645	77.7	23° 30′ N.	110° 31′ W.	90	33	100	BB
Sep. 15	24° 20′ N.	112° 00′ W.	645	77.7	22° 51′ N.	110° 22′ W.	149	104	127	BB
Sep. 16	24° 20′ N.	112° 00′ W.	605	81.0	23° 01′ N.	109° 28′ W.	295	295	171	PS
Sep. 16	24° 20′ N.	112° 00′ W.	610	81.0	23° 30′ N.	110° 35′ W.	78	--	92	BB
Sep. 16	24° 20′ N.	112° 00′ W.	610	81.0	23° 32′ N.	110° 37′ W.	80	--	93	BB
Sep. 16	24° 20′ N.	112° 00′ W.	615	81.0	23° 25′ N.	110° 09′ W.	100	--	79	BB
Sep. 16	24° 20′ N.	112° 00′ W.	620	81.0	23° 27′ N.	110° 20′ W.	92	77	106	BB
Sep. 16	24° 20′ N.	112° 00′ W.	625	81.0	23° 35′ N.	110° 35′ W.	71	5	89	BB
Sep. 16	24° 20′ N.	112° 00′ W.	635	81.0	23° 19′ N.	110° 38′ W.	77	18	96	BB
Sep. 17	24° 20′ N.	112° 00′ W.	590	81.5	23° 30′ N.	110° 35′ W.	87	78	92	BB
Sep. 17	24° 20′ N.	112° 00′ W.	610	81.5	23° 25′ N.	111° 50′ W.	21	—14	50	BB
Sep. 17	24° 20′ N.	112° 00′ W.	615	81.5	23° 27′ N.	110° 20′ W.	71	26	106	BB
1956										
July 23	24° 38′ N.	112° 31′ W.	500	83.8	23° 50′ N.	111° 40′ W.	90	--	66	BB
July 23	24° 38′ N.	112° 31′ W.	525	83.8	27° 28′ N.	114° 56′ W.	63	57	216	BB
July 24	24° 27′ N.	112° 33′ W.	570	78.8	25° 36′ N.	113° 25′ W.	842	768	89	BB
July 31	24° 46′ N.	112° 42′ W.	540	80.4	25° 04′ N.	112° 42′ W.	3		18	PS
1958										
May 22	23° 20′ N.	111° 03′ W.	500	71.2	25° 44′ N.	113° 12′ W.	80	64	184	PS
May 22	23° 20′ N.	111° 03′ W.	505	71.2	26° 18′ N.	113° 25′ W.	68	61	218	PS
May 22	23° 20′ N.	111° 03′ W.	510	71.2	25° 44′ N.	113° 09′ W.	86	--	185	PS
May 22	23° 20′ N.	111° 03′ W.	520	71.2	25° 44′ N.	113° 10′ W.	72–76	--	185	PS
May 22	23° 20′ N.	111° 03′ W.	550	71.2	25° 44′ N.	113° 09′ W.	61	58	185	--
May 22	23° 20′ N.	111° 03′ W.	550	71.2	25° 21′ N.	112° 51′ W.	65	40	155	BB
May 22	23° 20′ N.	111° 03′ W.	560	71.2	25° 30′ N.	113° 15′ W.	26	—2	176	PS
May 22	23° 20′ N.	111° 03′ W.	560	71.2	25° 44′ N.	113° 12′ W.	98	74	186	PS
May 22	23° 20′ N.	111° 03′ W.	560	71.2	25° 21′ N.	112° 51′ W.	197	167	156	BB
May 22	23° 20′ N.	111° 03′ W.	560	71.2	25° 44′ N.	113° 07′ W.	199	183	185	BB
May 22	23° 20′ N.	111° 03′ W.	580	71.2	25° 21′ N.	112° 51′ W.	73–76	--	155	BB
May 22	23° 20′ N.	111° 03′ W.	580	71.2	28° 20′ N.	115° 36′ W.	96	163	390	--
May 22	23° 20′ N.	111° 03′ W.	580	71.2	25° 44′ N.	113° 12′ W.	101	79	186	PS
May 22	23° 20′ N.	111° 03′ W.	585	71.2	25° 44′ N.	113° 09′ W.	80	73	185	PS
May 22	23° 20′ N.	111° 03′ W.	590	71.2	24° 14′ N.	109° 36′ W.	314	--	183	PS

APPENDIX A—Continued

Release and Recovery Data for 263 Pacific Yellowfin Tuna Tags Returned, 1952 Through 1958

Release					Recovery					
Date	Latitude	Longitude	Length (mm.)	Surface temperature (degrees F.)	Latitude	Longitude	Days at liberty	Increment (mm.)	Distance traveled (miles)	Recovery gear*
May 22	23° 20′ N.	111° 03′ W.	600	71.2	25° 44′ N.	113° 09′ W.	79	38	185	PS
May 22	23° 20′ N.	111° 03′ W.	600	71.2	25° 23′ N.	112° 53′ W.	80	74	157	PS
May 22	23° 20′ N.	111° 03′ W.	620	71.2	26° 06′ N.	113° 28′ W.	75	87	210	PS
May 22	23° 20′ N.	111° 03′ W.	620	71.2	25° 44′ N.	113° 12′ W.	80	48	184	PS
May 22	23° 20′ N.	111° 03′ W.	630	71.2	25° 44′ N.	113° 09′ W.	74	46	185	PS
May 22	23° 20′ N.	111° 03′ W.	630	71.2	25° 44′ N.	113° 10′ W.	80	17	185	PS
May 22	23° 20′ N.	111° 03′ W.	640	71.2	23° 42′ N.	111° 32′ W.	34	19	35	BB
May 22	23° 20′ N.	111° 03′ W.	650	71.2	25° 21′ N.	112° 51′ W.	83	26	165	PS
May 22	23° 20′ N.	111° 03′ W.	655	71.2	23° 40′ N.	111° 44′ W.	47	—8	44	BB
May 22	23° 20′ N.	111° 03′ W.	670	71.2	25° 44′ N.	113° 07′ W.	37	—5	184	PS
May 22	23° 20′ N.	111° 03′ W.	675	71.2	25° 44′ N.	113° 10′ W.	75	--	185	PS
May 22	23° 20′ N.	111° 03′ W.	695	71.2	26° 05′ N.	113° 30′ W.	41	30	215	BB
May 22	23° 20′ N.	111° 03′ W.	750	71.2	23 40′ N.	111° 44′ W.	47	3	46	BB
May 23	23° 20′ N.	111° 03′ W.	545	69.4	25° 44′ N.	113° 12′ W.	86	52	186	PS
May 23	23° 20′ N.	111° 03′ W.	590	69.4	--	--	32–39	--	--	BB
May 23	23° 20′ N.	111° 03′ W.	605	69.4	26° 19′ N.	113° 26′ W.	68	75	220	PS
May 23	23° 20′ N.	111° 03′ W.	610	69.4	25° 44′ N.	113° 09′ W.	74	59	185	PS
May 23	23° 20′ N.	111° 03′ W.	620	69.4	23° 43′ N.	111° 20′ W.	36	12	28	BB
May 23	23° 20′ N.	111° 03′ W.	625	69.4	25° 12′ N.	113° 02′ W.	27	—3	155	PS
May 23	23° 20′ N.	111° 03′ W.	625	69.4	25° 21′ N.	112° 51′ W.	--	8	155	BB
May 23	23° 20′ N.	111° 03′ W.	635	69.4	25° 36′ N.	113° 25′ W.	26	—1	188	PS
May 23	23° 20′ N.	111° 03′ W.	695	69.4	25° 08′ N.	113° 44′ W.	48	--	178	PS
May 24	23° 20′ N.	111° 03′ W.	515	70.3	25° 34′ N.	113° 10′ W.	79	--	175	PS
May 24	23° 20′ N.	111° 03′ W.	520	70.3	25° 44′ N.	113° 12′ W.	69	55	184	BB
May 24	23° 20′ N.	111° 03′ W.	540	70.3	25° 44′ N.	113° 12′ W.	78	29	184	PS
May 24	23° 20′ N.	111° 03′ W.	550	70.3	25° 50′ N.	113° 20′ W.	71	41	195	PS
May 24	23° 20′ N.	111° 03′ W.	560	70.3	25° 44′ N.	113° 12′ W.	99	--	186	PS
May 24	23° 20′ N.	111° 03′ W.	560	70.3	--	--	--	8	--	PS

May 24	23° 20′ N.	111° 03′ W.	560	70.3	26° 50′ N.	114° 10′ W.	501	452	252	PS
May 24	23° 20′ N.	111° 03′ W.	565	70.3	25° 44′ N.	113° 09′ W.	66	5	185	BB
May 24	23° 20′ N.	111° 03′ W.	570	70.3	25° 21′ N.	112° 51′ W.	79	42	155	PS
May 24	23° 20′ N.	111° 03′ W.	610	70.3	25° 44′ N.	113° 10′ W.	69	--	185	PS
May 27	23° 19′ N.	112° 00′ W.	665	70.7	23° 40′ N.	111° 43′ W.	31–33	—23	27	BB
May 27	23° 19′ N.	112° 00′ W.	670	70.7	23° 40′ N.	111° 44′ W.	30	--	24	BB
May 29	24° 08′ N.	111° 44′ W.	610	70.8	25° 57′ N.	113° 09′ W.	--	--	132	PS
May 29	24° 08′ N.	111° 44′ W.	625	70.8	24° 44′ N.	112° 16′ W.	22	—21	45	PS
May 29	24° 08′ N.	111° 44′ W.	660	70.8	--	--	--	16	--	PS
May 30	24° 08′ N.	111° 44′ W.	460	72.3	23° 50′ N.	111° 42′ W.	41	--	20	BB
May 30	24° 08′ N.	111° 44′ W.	470	72.3	23° 29′ N.	111° 10′ W.	13	--	48	--
May 30	24° 08′ N.	111° 44′ W.	570	72.3	26° 16′ N.	113° 35′ W.	78	36	162	PS
May 30	24° 08′ N.	111° 44′ W.	625	72.3	25° 44′ N.	113° 10′ W.	67	11	120	PS
May 30	24° 08′ N.	111° 44′ W.	640	72.3	25° 44′ N.	113° 07′ W.	26	52	125	PS
May 30	24° 08′ N.	111° 44′ W.	640	72.3	28° 20′ N.	115° 36′ W.	88	122	325	BB
May 30	24° 08′ N.	111° 44′ W.	645	72.3	--	--	--	--	--	BB
May 30	24° 08′ N.	111° 44′ W.	660	72.3	24° 11′ N.	111° 43′ W.	56	--	3	BB
May 30	24° 08′ N.	111° 44′ W.	665	72.3	25° 45′ N.	113° 00′ W.	25	—7	118	PS
May 31	23° 45′ N.	112° 00′ W.	530	70.9	25° 34′ N.	113° 10′ W.	72	--	128	PS
May 31	23° 45′ N.	112° 00′ W.	590	70.9	25° 44′ N.	113° 12′ W.	85	47	136	PS
May 31	23° 45′ N.	112° 00′ W.	595	70.9	25° 44′ N.	113° 12′ W.	62	72	136	BB
May 31	23° 45′ N.	112° 00′ W.	600	70.9	25° 44′ N.	113° 10′ W.	67–68	--	135	PS
May 31	23° 45′ N.	112° 00′ W.	610	70.9	25° 23′ N.	112° 53′ W.	73	34	108	PS
May 31	23° 45′ N.	112° 00′ W.	620	70.9	25° 44′ N.	112° 50′ W.	24	—16	126	PS
May 31	23° 45′ N.	112° 00′ W.	625	70.9	25° 36′ N.	113° 25′ W.	20	1	136	PS
May 31	23° 45′ N.	112° 00′ W.	630	70.9	25° 23′ N.	112° 53′ W.	73	--	108	PS
May 31	23° 45′ N.	112° 00′ W.	640	70.9	25° 35′ N.	113° 26′ W.	60–68	--	135	PS
May 31	23° 45′ N.	112° 00′ W.	645	70.9	25° 10′ N.	112° 51′ W.	17	—24	97	PS
May 31	23° 45′ N.	112° 00′ W.	645	70.9	24° 58′ N.	112° 35′ W.	19	—20	78	PS
May 31	23° 45′ N.	112° 00′ W.	650	70.9	--	--	20–24	—13	--	PS
May 31	23° 45′ N.	112° 00′ W.	650	70.9	25° 44′ N.	113° 09′ W.	67	47	136	PS
May 31	23° 45′ N.	112° 00′ W.	650	70.9	25° 44′ N.	113° 12′ W.	71	43	134	PS
May 31	23° 45′ N.	112° 00′ W.	655	70.9	25° 06′ N.	112° 51′ W.	15–17	—7	92	PS
May 31	23° 45′ N.	112° 00′ W.	660	70.9	25° 05′ N.	112° 40′ W.	16	—4	87	PS
May 31	23° 45′ N.	112° 00′ W.	660	70.9	25° 21′ N.	112° 51′ W.	74	83	128	PS
May 31	23° 45′ N.	112° 00′ W.	670	70.9	25° 06′ N.	112° 51′ W.	15–17	—8	92	PS
May 31	23° 45′ N.	112° 00′ W.	670	70.9	--	--	20–24	--	--	PS
May 31	23° 45′ N.	112° 00′ W.	670	70.9	25° 44′ N.	113° 00′ W.	24	—15	131	PS
May 31	23° 45′ N.	112° 00′ W.	680	70.9	--	--	--	--	--	PS
May 31	23° 45′ N.	112° 00′ W.	685	70.9	25° 36′ N.	113° 25′ W.	20	—26	136	PS
May 31	23° 45′ N.	112° 00′ W.	690	70.9	25° 36′ N.	113° 25′ W.	19	0	136	PS
May 31	23° 45′ N.	112° 00′ W.	705	70.9	25° 00′ N.	112° 30′ W.	17	—8	79	PS
May 31	23° 45′ N.	112° 00′ W.	710	70.9	26° 38′ N.	114° 10′ W.	61	31	210	PS

APPENDIX A—Continued

Release and Recovery Data for 263 Pacific Yellowfin Tuna Tags Returned, 1952 Through 1958

Release					Recovery					
Date	Latitude	Longitude	Length (mm.)	Surface temperature (degrees F.)	Latitude	Longitude	Days at liberty	Increment (mm.)	Distance traveled (miles)	Recovery gear*
May 31	23° 45′ N.	112° 00′ W.	710	70.9	25° 44′ N.	113° 09′ W.	64	67	130	PS
May 31	23° 45′ N.	112° 00′ W.	710	70.9	25° 44′ N.	113° 12′ W.	76–77	--	136	PS
May 31	23° 45′ N.	112° 00′ W.	720	70.9	25° 10′ N.	112° 42′ W.	17	—13	94	PS
May 31	23° 45′ N.	112° 00′ W.	740	70.9	25° 58′ N.	113° 27′ W.	22	—17	155	PS
June 1	23° 45′ N.	112° 00′ W.	625	70.3	24° 58′ N.	112° 35′ W.	16	—5	78	PS
June 1	23° 45′ N.	112° 00′ W.	665	70.3	25° 44′ N.	113° 09′ W.	65	--	135	PS
June 1	23° 45′ N.	112° 00′ W.	670	70.3	24° 44′ N.	112° 16′ W.	19	—21	60	PS
June 1	23° 45′ N.	112° 00′ W.	680	70.3	25° 30′ N.	113° 15′ W.	20	—16	124	PS
June 1	23° 45′ N.	112° 00′ W.	690	70.3	25° 21′ N.	112° 51′ W.	15	2	108	PS
June 1	23° 45′ N.	112° 00′ W.	710	70.3	25° 44′ N.	113° 09′ W.	23	—1	136	PS
June 17	24° 41′ N.	112° 35′ W.	520	67.8	25° 44′ N.	113° 07′ W.	10	--	71	PS
June 17	24° 41′ N.	112° 35′ W.	595	67.8	25° 21′ N.	112° 51′ W.	6	—15	43	PS
June 17	24° 41′ N.	112° 35′ W.	725	67.8	25° 44′ N.	113° 10′ W.	46–50	35	70	PS
June 28	23° 55′ N.	111° 23′ W.	600	74.7	--	--	--	--	--	--
June 28	23° 55′ N.	111° 23′ W.	650	74.7	25° 44′ N.	113° 10′ W.	34	--	145	PS
June 28	23° 55′ N.	111° 23′ W.	665	74.7	25° 58′ N.	113° 12′ W.	36	7	160	PS
June 28	23° 55′ N.	111° 23′ W.	665	74.7	25° 44′ N.	113° 10′ W.	35–39	--	145	PS
June 28	23° 55′ N.	111° 23′ W.	690	74.7	--	--	--	80	--	PS
June 28	23° 55′ N.	111° 23′ W.	700	74.7	23° 50′ N.	111° 42′ W.	12	—37	18	BB
June 29	24° 52′ N.	112° 57′ W.	510	70.7	25° 44′ N.	113° 12′ W.	60	27	54	PS
June 29	24° 52′ N.	112° 57′ W.	555	70.7	25° 44′ N.	113° 10′ W.	63	--	48	PS
June 29	25° 06′ N.	112° 45′ W.	570	70.7	25° 39′ N.	113° 26′ W.	20	—3	50	BB
June 29	25° 06′ N.	112° 45′ W.	610	70.7	25° 44′ N.	113° 12′ W.	60	--	16	PS
June 29	25° 06′ N.	112° 45′ W.	690	70.7	26° 00′ N.	112° 45′ W.	39	--	54	BB

July 1	26° 01′ N.	114° 19′ W.	510	67.1	25° 44′ N.	113° 09′ W.	35	—2	75	PS
July 1	26° 01′ N.	114° 19′ W.	510	67.1	27° 36′ N.	114° 56′ W.	111	129	102	BB
July 1	26° 01′ N.	114° 19′ W.	510	67.1	26° 01′ N.	113° 38′ W.	191	176	32	--
July 1	26° 01′ N.	114° 19′ W.	530	67.1	28° 30′ N.	115° 30′ W.	130	--	160	BB
July 1	26° 01′ N.	114° 19′ W.	545	67.1	27° 30′ N.	115° 30′ W.	63	61	110	BB
July 1	26° 01′ N.	114° 19′ W.	550	67.1	28° 20′ N.	115° 52′ W.	117	115	163	BB
July 1	26° 01′ N.	114° 19′ W.	550	67.1	27° 30′ N.	115° 14′ W.	409	--	92	PS
July 1	26° 01′ N.	114° 19′ W.	560	67.1	28° 28′ N.	115° 44′ W.	121	--	164	BB
July 1	26° 01′ N.	114° 19′ W.	570	67.1	27° 37′ N.	115° 00′ W.	118	105	102	BB
July 17	26° 46′ N.	114° 28′ W.	550	69.2	19° 20′ N.	110° 51′ W.	137	--	487	PS
July 24	26° 16′ N.	114° 19′ W.	525	71.7	26° 38′ N.	114° 00′ W.	233	161	28	BB
Aug. 1	25° 46′ N.	113° 02′ W.	480	75.2	25° 21′ N.	112° 51′ W.	8	1	25	PS
Aug. 1	25° 46′ N.	113° 02′ W.	550	75.2	25° 21′ N.	112° 51′ W.	8	—6	25	PS
Aug. 2	25° 44′ N.	113° 07′ W.	560	78.8	25° 44′ N.	113° 07′ W.	3	--	0	PS
Aug. 2	25° 44′ N.	113° 07′ W.	560	78.8	25° 21′ N.	112° 51′ W.	8	—10	23	PS
Aug. 2	25° 44′ N.	113° 07′ W.	580	78.8	25° 44′ N.	113° 07′ W.	3	3	0	PS
Aug. 2	25° 44′ N.	113° 09′ W.	515	78.6	25° 44′ N.	113° 07′ W.	1	--	2	BB
Aug. 3	25° 38′ N.	113° 07′ W.	--	77.8	25° 12′ N.	112° 50′ W.	364	--	25	PS
1953	Revilla Gigedo Islands									
June 21	18° 22′ N.	114° 41′ W.	580	--	23° 53′ N.	111° 16′ W.	45	19	381	PS
1956										
July 31	18° 43′ N.	112° 06′ W.	930	82.2	18° 54′ N.	110° 56′ W.	239	147	66	PS
Aug. 12	19° 00′ N.	111° 49′ W.	990	83.8	19° 20′ N.	110° 51′ W.	262	192	60	PS
1957										
June 2	18° 23′ N.	114° 44′ W.	820	75						
1958										
May 13	18° 52′ N.	110° 57′ W.	625	79.7	23° 55′ N.	111° 23′ W.	47	25	300	BB
May 14	18° 52′ N.	110° 57′ W.	735	79.7	18° 54′ N.	110° 56′ W.	183	72	0	BB
May 15	19° 00′ N.	112° 09′ W.	530	80.1	19° 00′ N.	112° 09′ W.	23	—1	0	BB
May 18	18° 21′ N.	114° 42′ W.	600	76.6	23° 35′ N.	111° 39′ W.	36	--	358	PS
1952	Mexico (North)									
Mar. 7	19° 20′ N.	105° 55′ W.	--	--	22° 56′ N.	109° 29′ W.	75	--	294	PS
Mar. 7	19° 20′ N.	105° 55′ W.	--	--	22° 56′ N.	109° 29′ W.	100–102	--	318	PS
Mar. 8	21° 07′ N.	108° 19′ W.	470	--	21° 47′ N.	111° 20′ W.	106	22	176	BB
1956										
Dec. 3	21° 56′ N.	106° 30′ W.	583	79	22° 08′ N.	106° 30′ W.	91	95	27	BB
Dec. 3	21° 56′ N.	106° 30′ W.	688	79	19° 29′ N.	105° 18′ W.	160	110	162	PS

APPENDIX A—Continued

Release and Recovery Data for 263 Pacific Yellowfin Tuna Tags Returned, 1952 Through 1958

Release					Recovery					
Date	Latitude	Longitude	Length (mm.)	Surface temperature (degrees F.)	Latitude	Longitude	Days at liberty	Increment (mm.)	Distance traveled (miles)	Recovery gear*
1957										
June 26	21° 15′ N.	106° 15′ W.	790	82	21° 34′ N.	106° 26′ W.	80	115	22	BB
1952	**Mexico (South)**									
Apr. 23	17° 00′ N.	101° 02′ W.	--	--	16° 40′ N.	102° 07′ W.	10	--	70	PS
1954	**Tehuantepec**									
Apr. 2	15° 22′ N.	97° 37′ W.	570	80.5	17° 05′ N.	101° 10′ W.	20	—5	225	PS
1955										
Feb. 19	14° 47′ N.	98° 00′ W.	600	80–82	19° 00′ N.	112° 10′ W.	273	362	853	BB
Feb. 19	14° 47′ N.	98° 00′ W.	695	80–82	24° 32′ N.	112° 36′ W.	178	186	1,025	BB
Feb. 20	14° 48′ N.	98° 00′ W.	700	82	25° 42′ N.	110° 28′ W.	109	--	980	PS
Feb. 20	14° 48′ N.	98° 00′ W.	710	82	19° 16′ N.	110° 51′ W.	235	209	793	BB
1957										
Apr. 6	13° 04′ N.	89° 53′ W.	770	84	13° 07′ N.	92° 39′ W.	27	--	160	BB
June 11	14° 45′ N.	97° 10′ W.	810	85	10° 15′ N.†	109° 15′ W.†	156	--	750	BB
1954	**Central America**									
Mar. 25	10° 45′ N.	86° 16′ W.	600	--	10° 35′ N.	86° 10′ W.	19	4	15	BB
Apr. 24	08° 53′ N.	85° 06′ W.	630	84	10° 35′ N.	86° 25′ W.	104	124	130	BB
1955										
Jan. 21	11° 02′ N.	86° 43′ W.	570	76.5	10° 40′ N.	86° 25′ W.	125	113	35	BB
1957										
Mar. 8	12° 58′ N.	90° 12′ W.	780	80	18° 45′ N.	104° 05′ W.	63	34	880	PS
Mar. 8	12° 58′ N.	90° 12′ W.	780	80	17° 03′ N.	101° 04′ W.	102	25	700	BB
Apr. 15	12° 48′ N.	89° 44′ W.	740	84	13° 35′ N.	92° 12′ W.	16	—20	158	BB

1955	Panama								
Feb. 5	08° 43′ N.	79° 03′ W.	648	83.5	10° 05′ N.	86° 11′ W.	130	100	520	BB
1952	Guayaquil								
Dec. 16	03° 35′ S.	80° 56′ W.	601	77	09° 05′ S.	79° 52′ W.	372	332	350	BB
Dec. 16	03° 35′ S.	80° 56′ W.	610	77	04° 06′ S.	81° 08′ W.	33	12	30	PS
1954										
Oct. 20	03° 30′ S.	81° 12′ W.	495	--	03° 30′ S.	80° 54′ W.	25	--	18	PS
Oct. 20	03° 30′ S.	81° 12′ W.	595	--	07° 10′ S.	80° 53′ W.	150	--	218	PS
Oct. 20	03° 30′ S.	81° 12′ W.	670	--	--	--	--	--	--	--
Oct. 21	03° 13′ S.	81° 02′ W.	500	--	03° 29′ S.	81° 06′ W.	33	+21	16	BB
Oct. 21	03° 13′ S.	81° 02′ W.	555	--	03° 17′ S.	81° 01′ W.	14	0	4	BB
Oct. 21	03° 13′ S.	81° 02′ W.	560	--	03° 30′ S.	81° 10′ W.	27	4	20	BB
Oct. 21	03° 13′ S.	81° 02′ W.	565	--	03° 30′ S.	81° 10′ W.	--	0	20	BB
Oct. 21	03° 13′ S.	81° 02′ W.	570	--	02° 30′ S.	81° 00′ W.	--	—12	45	BB
Oct. 23	03° 55′ S.	81° 00′ W.	580	--	03° 30′ S.	81° 10′ W.	26	8	30	BB
Nov. 12	03° 30′ S.	81° 10′ W.	620	72	03° 33′ S.	81° 21′ W.	8	+—7	20	BB
Nov. 13	03° 30′ S.	81° 10′ W.	590	72	03° 30′ S.	81° 10′ W.	13	—22	0	BB
Nov. 19	03° 30′ S.	81° 10′ W.	575	72	--	--	--	—11	--	--
Dec. 10	02° 28′ S.	81° 02′ W.	505	70	03° 30′ S.	81° 10′ W.	105	72	65	PS
1957										
Nov. 28	03° 30′ S.	81° 10′ W.	470	73	03° 30′ S.	81° 10′ W.	359	--	0	PS
Dec. 2	03° 30′ S.	81° 10′ W.	670	73.8	03° 47′ S.	81° 05′ W.	423	--	19	BO
1958										
Oct. 12	03° 24′ S.	81° 08′ W.	520	67.2	03° 24′ S.	81° 08′ W.	19	--	0	BB
Oct. 13	03° 24′ S.	81° 12′ W.	480	74.3	03° 30′ S.	80° 45′ W.	193	--	28	BO
Oct. 13	03° 24′ S.	81° 12′ W.	505	74.3	04° 03′ S.	81° 09′ W.	80–110	--	40	PS
Oct. 13	03° 24′ S.	81° 12′ W.	525	74.3	03° 26′ S.	81° 01′ W.	19	7	11	BB
Oct. 13	03° 24′ S.	81° 12′ W.	550	74.3	03° 26′ S.	81° 01′ W.	12–44	—10	11	BB
Oct. 19	04° 10′ S.	81° 38′ W.	530	71.7	03° 32′ S.	81° 02′ W.	105	--	50	BO
Oct. 19	04° 14′ S.	81° 36′ W.	555	71.7	03° 40′ S.	81° 00′ W.	40	0	50	BB
Oct. 19	04° 14′ S.	81° 36′ W.	565	71.7	02° 33′ S.	80° 58′ W.	16	0	108	BB
Oct. 20	04° 10′ S.	81° 42′ W.	495	71.4	09° 04′ S.	79° 55′ W.	243	--	356	BB
Oct. 20	04° 10′ S.	81° 42′ W.	575	71.4	03° 59′ S.	81° 02′ W.	61	--	42	BO
Oct. 31	03° 16′ S.	81° 01′ W.	520	--	03° 40′ S.	81° 41′ W.	197	--	32	PS

APPENDIX A—Continued

Release and Recovery Data for 263 Pacific Yellowfin Tuna Tags Returned, 1952 Through 1958

Release					Recovery					
Date	Latitude	Longitude	Length (mm.)	Surface temperature (degrees F.)	Latitude	Longitude	Days at liberty	Increment (mm.)	Distance traveled (miles)	Recovery gear*
Nov. 9	03° 41′ S.	81° 04′ W.	540	72.8	03° 41′ S.	81° 04′ W.	144	--	0	BO
Nov. 9	03° 41′ S.	81° 04′ W.	585	72.8	04° 03′ S.	81° 15′ W.	68	--	25	BO
Nov. 9	03° 41′ S.	81° 04′ W.	625	72.8	09° 04′ S.	79° 55′ W.	118–141	124	352	BB
Nov. 10	03° 44′ S.	81° 00′ W.	600	71.6	03° 40′ S.	81° 00′ W.	18	3	4	BB
Nov. 13	03° 34′ S.	81° 12′ W.	510	71.8	03° 29′ S.	81° 04′ W.	53	60	13	BB
1957	Peru (North)									
Dec. 2	09° 03′ S.	79° 55′ W.	680	66	09° 03′ S.	79° 55′ W.	64	--	0	BB
1958										
Nov. 5	09° 05′ S.	79° 57′ W.	560	67.2	09° 05′ S.	79° 57′ W.	6	1	0	BB
Nov. 5	09° 05′ S.	79° 57′ W.	575	67.2	09° 05′ S.	79° 57′ W.	3	2	0	BB
Nov. 5	09° 05′ S.	79° 57′ W.	590	67.2	09° 05′ S.	79° 57′ W.	5	10	0	BB
Nov. 5	09° 05′ S.	79° 57′ W.	590	67.2	09° 05′ S.	79° 57′ W.	5	--	0	BB
Nov. 5	09° 05′ S.	79° 57′ W.	595	67.2	09° 05′ S.	79° 57′ W.	5	--	0	BB
Nov. 5	09° 05′ S.	79° 57′ W.	595	67.2	09° 05′ S.	79° 57′ W.	6	—5	0	BB
Nov. 5	09° 05′ S.	79° 57′ W.	600	67.2	09° 05′ S.	79° 55′ W.	123	--	2	BB
Nov. 5	09° 05′ S.	79° 57′ W.	610	67.2	09° 05′ S.	79° 57′ W.	4	--	0	BB
Nov. 5	09° 05′ S.	79° 57′ W.	610	67.2	09° 04′ S.	79° 55′ W.	16	—5	1	BB
Nov. 5	09° 05′ S.	79° 57′ W.	620	67.2	09° 05′ S.	79° 57′ W.	10	--	0	BB
Nov. 5	09° 05′ S.	79° 57′ W.	625	67.2	09° 05′ S.	79° 57′ W.	129	--	0	BB
Nov. 5	09° 05′ S.	79° 57′ W.	630	67.2	09° 05′ S.	79° 55′ W.	3	--	2	BB
Nov. 5	09° 05′ S.	79° 57′ W.	630	67.2	09° 05′ S.	79° 57′ W.	16	—32	0	BB
Nov. 5	09° 05′ S.	79° 57′ W.	635	67.2	03° 32′ S.	81° 12′ W.	--	13	344	BB
Nov. 5	09° 05′ S.	79° 57′ W.	645	67.2	03° 32′ S.	81° 12′ W.	16	—5	344	BB
Nov. 5	09° 05′ S.	79° 57′ W.	655	67.2	--	--	76–80	--	--	BB

1952	Galapagos Islands									
Nov. 30	01° 38′ N.	92° 00′ W.	585	78.5	01° 40′ N.	92° 06′ W.	49	10	6	BB
1954										
Feb. 22	00° 16′ N.	91° 37′ W.	525	71	00° 16′ N.	91° 37′ W.	6	—12	0	BB
Mar. 11	01° 15′ N.	91° 06′ W.	505	81	03° 24′ S.	81° 11′ W.	229	53	640	BB
Sept. 28	02° 12′ N.	91° 11′ W.	500	--	00° 25′ S.	90° 42′ W.	79	15	110	BB

* PS—purse seiner, BB—bait boat, BO—bolichero.
† This fish may have been recovered at New Clarion Bank, Nov. 13-26, 1957.
‡ Species in doubt.

APPENDIX B

Release and Recovery Data for 237 Skipjack Tags Returned, 1953 Through 1959

Release					Recovery					
Date	Latitude	Longitude	Fish length (mm.)	Surface temperature (degrees F.)	Latitude	Longitude	Days at liberty	Fish length (mm.)	Distance traveled (miles)	Recovery gear*
1953	**Baja California**									
June 25	22° 25′ N.	112° 03′ W.	515	71	23° 48′ N.	111° 24′ W.	42	528	92	PS
July 2	22° 38′ N.	112° 03′ W.	520	74	--	--	1–6	--	--	PS
July 2	22° 37′ N.	111° 59′ W.	495	74	23° 40′ N.	112° 08′ W.	11	--	71	BB
July 6	23° 37′ N.	112° 10′ W.	515	74	23° 15′ N.	112° 02′ W.	12	--	23	BB
July 13	23° 00′ N.	113° 00′ W.	445	75.2	23° 44′ N.	113° 04′ W.	13	447	45	BB
July 13	23° 00′ N.	113° 00′ W.	490	75.2	23° 29′ N.	113° 02′ W.	13	494	29	BB
July 17	23° 27′ N.	111° 52′ W.	480	77.8	23° 08′ N.	113° 03′ W.	14	487	68	BB
July 17	23° 27′ N.	111° 52′ W.	490	77.5	22° 24′ N.	112° 54′ W.	8	494	85	BB
July 21	23° 45′ N.	112° 00′ W.	480	--	23° 05′ N.	111° 52′ W.	3	465	40	PS
July 21	23° 00′ N.	111° 55′ W.	485	76.5	23° 05′ N.	111° 52′ W.	3	484	5	PS
July 21	23° 00′ N.	111° 55′ W.	520	76.5	25° 20′ N.	112° 50′ W.	31	530	151	PS
July 21	23° 00′ N.	111° 55′ W.	535	76.5	24° 09′ N.	112° 23′ W.	20	--	74	PS
July 23	23° 43′ N.	113° 11′ W.	565	76.5	27° 05′ N.	114° 55′ W.	34	557	212	BB
July 25	25° 23′ N.	113° 32′ W.	515	76.5	24° 48′ N.	112° 43′ W.	21	530	57	PS
July 25	25° 23′ N.	113° 32′ W.	540	76.5	25° 37′ N.	113° 15′ W.	2	548	20	PS
July 25	25° 23′ N.	113° 32′ W.	545	76.5	--	--	11 or 21	547	--	PS
July 25	25° 23′ N.	113° 32′ W.	555	76.5	25° 37′ N.	113° 15′ W.	2	556	20	PS
July 27	25° 35′ N.	113° 23′ W.	530	76.5	25° 35′ N.	113° 25′ W.	1	529	2	PS
July 27	25° 35′ N.	113° 23′ W.	540	76.5	25° 35′ N.	113° 23′ W.	1	--	0	PS
July 27	25° 35′ N.	113° 23′ W.	545	76.5	25° 36′ N.	112° 30′ W.	39	539	40	PS
1955										
Sept. 12	25° 30′ N.	113° 25′ W.	540	76	23° 35′ N.	110° 47′ W.	71	--	188	BB
Sept. 16	24° 20′ N.	112° 00′ W.	510	82	23° 32′ N.	110° 32′ W.	77	533	91	TR

1956										
July 11	23° 35′ N.	112° 12′ W.	465	76.6	24° 56′ N.	112° 35′ W.	20	473	85	PS
July 11	23° 35′ N.	112° 12′ W.	515	76.6	--	--	--	--	--	BB
July 13	23° 35′ N.	112° 12′ W.	470	74.3	24° 15′ N.	112° 26′ W.	25	--	42	BB
July 13	23° 35′ N.	112° 12′ W.	510	74.3	24° 20′ N.	112° 00′ W.	25	485	47	BB
July 13	23° 35′ N.	112° 12′ W.	545	74.3	25° 36′ N.	113° 26′ W.	46	549	139	BB
July 29	24° 46′ N.	112° 41′ W.	445	81.3	24° 18′ N.	112° 16′ W.	20	455	39	BB
1958										
May 23	23° 20′ N.	111° 03′ W.	--	69.4	23° 40′ N.	111° 44′ W.	32	--	45	BB
May 23	23° 20′ N.	111° 03′ W.	--	69.4	25° 44′ N.	113° 10′ W.	76–78	--	185	PS
May 27	23° 19′ N.	112° 00′ W.	--	70.7	24° 55′ N.	112° 46′ W.	21–22	--	103	PS
May 27	23° 19′ N.	112° 00′ W.	--	70.7	25° 57′ N.	113° 12′ W.	24	--	170	PS
May 29	24° 08′ N.	111° 44′ W.	--	70.8	23° 48′ N.	111° 32′ W.	28	--	24	BB
May 29	24° 08′ N.	111° 44′ W.	--	70.8	25° 44′ N.	113° 10′ W.	66	--	120	BB
May 30	24° 08′ N.	111° 44′ W.	--	72.3	25° 10′ N.	112° 51′ W.	18	--	86	PS
May 30	24° 08′ N.	111° 44′ W.	--	72.3	23° 40′ N.	111° 43′ W.	28–30	507	30	BB
May 30	24° 08′ N.	111° 44′ W.	--	72.3	26° 08′ N.	113° 40′ W.	31	563	150	BB
May 30	24° 08′ N.	111° 44′ W.	--	72.3	25° 44′ N.	113° 09′ W.	66	--	120	PS
May 30	24° 08′ N.	111° 44′ W.	--	72.3	25° 21′ N.	112° 51′ W.	69	--	95	BB
May 30	24° 08′ N.	111° 44′ W.	--	72.3	--	--	--	--	--	--
May 30	24° 08′ N.	111° 44′ W.	--	72.3	--	--	--	--	--	PS
May 31	23° 45′ N.	112° 00′ W.	--	70.9	25° 35′ N.	113° 25′ W.	45	--	135	BB
May 31	23° 45′ N.	112° 00′ W.	--	70.9	25° 44′ N.	113° 12′ W.	56	555	134	BB
May 31	23° 45′ N.	112° 00′ W.	--	70.9	25° 21′ N.	112° 51′ W.	56	545	108	BB
May 31	23° 45′ N.	112° 00′ W.	--	70.9	25° 50′ N.	113° 20′ W.	62	--	145	PS
May 31	23° 45′ N.	112° 00′ W.	--	70.9	25° 44′ N.	113° 09′ W.	62–67	563	135	PS
May 31	23° 45′ N.	112° 00′ W.	--	70.9	25° 44′ N.	113° 10′ W.	63–67	602	135	PS
May 31	23° 45° N.	112° 00′ W.	--	70.9	--	--	--	578	--	BB
May 31	23° 45′ N.	112° 00′ W.	--	70.9	25° 44′ N.	113° 09′ W.	66	516	130	PS
May 31	23° 45′ N.	112° 00′ W.	--	70.9	25° 21′ N.	112° 51′ W.	68	578	108	BB
May 31	23° 45′ N.	112° 00′ W.	--	70.9	25° 44′ N.	113° 12′ W.	71	579	136	PS
May 31	23° 45′ N.	112° 00′ W.	--	70.9	28° 20′ N.	115° 35′ W.	78	575	330	PS
May 31	23° 45′ N.	112° 00′ W.	--	70.9	28° 20′ N.	115° 36′ W.	87	635	330	BB
May 31	23° 45′ N.	112° 00′ W.	--	70.9	25° 44′ N.	113° 12′ W.	89	584	136	PS
May 31	23° 45′ N.	112° 00′ W.	--	70.9	27° 53′ N.	115° 35′ W.	139	--	310	BB
June 1	23° 45′ N.	112° 00′ W.	--	70.3	25° 21′ N.	112° 51′ W.	53	--	105	BB
June 1	23° 45′ N.	112° 00′ W.	--	70.3	25° 44′ N.	113° 09′ W.	59	583	135	BB
June 1	23° 45′ N.	112° 00′ W.	--	70.3	26° 38′ N.	114° 10′ W.	60	559	210	PS
June 1	23° 45′ N.	112° 00′ W.	--	70.3	25° 37′ N.	113° 06′ W.	60	--	128	BB
June 14	24° 24′ N.	112° 20′ W.	--	66.9	25° 21′ N.	112° 51′ W.	51–55	--	65	BB
June 16	24° 41′ N.	112° 35′ W.	--	68	25° 21′ N.	112° 51′ W.	2	593	44	PS

APPENDIX B—Continued

Release and Recovery Data for 237 Skipjack Tags Returned, 1953 Through 1959

Release					Recovery					
Date	Latitude	Longitude	Fish length (mm.)	Surface temperature (degrees F.)	Latitude	Longitude	Days at liberty	Fish length (mm.)	Distance traveled (miles)	Recovery gear*
June 16	24° 41′ N.	112° 35′ W.	--	68	25° 52′ N.	113° 15′ W.	36	635	80	BB
June 17	24° 41′ N.	112° 35′ W.	--	67.8	24° 50′ N.	112° 35′ W.	3	550	9	PS
June 17	24° 41′ N.	112° 35′ W.	--	67.8	23° 37′ N.	111° 41′ W.	10	--	80	BB
June 29	25° 06′ N.	112° 45′ W.	--	70.7	24° 58′ N.	112° 40′ W.	15	--	8	BB
June 29	25° 06′ N.	112° 45′ W.	--	70.7	27° 09′ N.	114° 30′ W.	134	--	154	BB
July 1	26° 01′ N.	114° 19′ W.	--	67.1	--	--	--	642	--	BB
July 4	26° 15′ N.	114° 30′ W.	--	66.9	26° 05′ N.	113° 36′ W.	132	679	18	BB
July 4	26° 15′ N.	114° 30′ W.	--	66.9	25° 30′ N.	113° 12′ W.	30	615	90	PS
July 4	26° 15′ N.	114° 30′ W.	--	66.9	28° 18′ N.	116° 12′ W.	38	606	160	PS
July 4	26° 15′ N.	114° 30′ W.	--	66.9	29° 20′ N.	117° 14′ W.	48	642	236	BB
July 4	26° 15′ N.	114° 30′ W.	--	66.9	32° 05′ N.	118° 15′ W.	90	642	400	BB
July 6	26° 15′ N.	114° 30′ W.	--	68.7	27° 19′ N.	115° 00′ W.	53–54	--	70	BB
July 6	26° 15′ N.	114° 30′ W.	--	68.7	28° 21′ N.	115° 32′ W.	86	--	138	BB
July 7	26° 15′ N.	114° 30′ W.	--	69.3	25° 30′ N.	113° 12′ W.	27	625	90	PS
July 20	26° 22′ N.	114° 28′ W.	--	69.8	24° 58′ N.	112° 35′ W.	103	638	134	BB
July 24	26° 16′ N.	114° 19′ W.	--	71.7	25° 36′ N.	113° 25′ W.	9	483	63	BB
July 24	26° 16′ N.	114° 19′ W.	--	71.7	32° 05′ N.	118° 15′ W.	71	--	403	BB
July 24	26° 16′ N.	114° 19′ W.	--	71.7	--	--	--	--	--	BB
July 24	26° 16′ N.	114° 19′ W.	--	71.7	--	--	--	--	--	BB
July 26	25° 47′ N.	113° 09′ W.	--	74.3	25° 44′ N.	113° 09′ W.	7–11	569	3	PS
July 28	26° 55′ N.	114° 36′ W.	--	66	24° 56′ N.	112° 34′ W.	58	540	159	BB
Aug. 2	25° 44′ N.	113° 07′ W.	--	78.8	25° 44′ N.	113° 09′ W.	4	605	2	PS
Aug. 2	25° 44′ N.	113° 07′ W.	--	78.8	25° 44′ N.	113° 09′ W.	4	562	2	PS
Aug. 3	25° 38′ N.	113° 07′ W.	--	78.8	25° 44′ N.	113° 09′ W.	1	514	6	BB
Aug. 5	25° 40′ N.	113° 08′ W.	--	76.8	25° 44′ N.	113° 09′ W.	1	--	4	PS
Aug. 5	25° 40′ N.	113° 08′ W.	--	76.8	25° 44′ N.	113° 07′ W.	1–2	567	4	PS
Aug. 5	25° 40′ N.	113° 08′ W.	--	76.8	25° 43′ N.	113° 09′ W.	2	508	3	PS

1956	Revilla Gigedo									
July 26	18° 55′ N.	111° 58′ W.	620	81.3	--	--	--	--	--	--
July 28	18° 47′ N.	111° 52′ W.	650	82.2	19° 00′ N.	112° 09′ W.	37	630	20	BB
July 28	18° 43′ N.	111° 45′ W.	670	82	18° 58′ N.	112° 03′ W.	18	665	23	BB
Aug. 12	19° 00′ N.	111° 50′ W.	580	83.8	19° 00′ N.	111° 50′ W.	32	572	0	BB
Aug. 12	19° 00′ N.	111° 50′ W.	690	83.8	18° 58′ N.	112° 04′ W.	49	616	14	BB
1958										
May 11	19° 00′ N.	112° 09′ W.	--	79.5	19° 00′ N.	112° 09′ W.	41–42	508	0	BB
May 11	19° 00′ N.	112° 09′ W.	--	79.5	19° 00′ N.	112° 09′ W.	41–42	536	0	BB
May 11	19° 00′ N.	112° 09′ W.	--	79.5	19° 00′ N.	112° 09′ W.	41–42	--	0	BB
May 11	19° 00′ N.	112° 09′ W.	--	79.5	19° 00′ N.	112° 09′ W.	42	469	0	BB
May 11	19° 00′ N.	112° 09′ W.	--	79.5	19° 00′ N.	112° 09′ W.	42	--	0	BB
May 11	19° 00′ N.	112° 09′ W.	--	79.5	25° 36′ N.	113° 25′ W.	52–58	--	410	BB
May 15	19° 00′ N.	112° 09′ W.	--	80.1	19° 00′ N.	112° 09′ W.	14	--	0	BB
May 15	19° 00′ N.	112° 09′ W.	--	80.1	19° 00′ N.	112° 09′ W.	14	--	0	BB
May 15	19° 00′ N.	112° 09′ W.	--	80.1	19° 00′ N.	112° 09′ W.	36–38	--	0	BB
May 15	19° 00′ N.	112° 09′ W.	--	80.1	19° 00′ N.	112° 09′ W.	37–38	--	0	BB
May 15	19° 00′ N.	112° 09′ W.	--	80.1	19° 00′ N.	112° 09′ W.	37–38	--	0	BB
May 16	19° 00′ N.	112° 09′ W.	--	79.7	19° 00′ N.	112° 09′ W.	13	--	0	BB
1956	Mexico (North)									
Nov. 12	20° 56′ N.	105° 51′ W.	600	82	21° 05′ N.	106° 06′ W.	27	594	18	BB
Dec. 2	22° 04′ N.	106° 34′ W.	575	78	21° 40′ N.	106° 38′ W.	85–86	608	24	BB
Dec. 3	21° 56′ N.	106° 30′ W.	507	81.7	--	--	--	--	--	BB
Dec. 3	21° 56′ N.	106° 30′ W.	560	79	--	--	--	--	--	--
Dec. 3	21° 56′ N.	106° 30′ W.	560	79	21° 58′ N.	106° 18′ W.	107	--	12	PS
Dec. 3	21° 56′ N.	106° 30′ W.	530	79	21° 55′ N.	106° 30′ W.	78	552	1	BB
1954	Central America									
Apr. 9	10° 32′ N.	86° 15′ W.	540	84.5	12° 20′ N.	87° 15′ W.	36	568	120	BB
Apr. 18	11° 50′ N.	87° 11′ W.	535	82	--	--	--	--	--	PS
Apr. 23	08° 52′ N.	85° 06′ W.	565	84	10° 53′ N.	86° 24′ W.	51	562	132	BB
1957										
May 28	10° 27′ N.	86° 13′ W.	--	84.6	10° 27′ N.	86° 13′ W.	55	--	0	BB
1954	Ecuador									
May 6	01° 16′ S.	81° 26′ W.	--	78	--	--	--	--	--	--

APPENDIX B—Continued

Release and Recovery Data for 237 Skipjack Tags Returned, 1953 Through 1959

Release					Recovery					
Date	Latitude	Longitude	Fish length (mm.)	Surface temperature (degrees F.)	Latitude	Longitude	Days at liberty	Fish length (mm.)	Distance traveled (miles)	Recovery gear*
1957										
July 2	01° 37′ S.	81° 10′ W.	--	78	--	--	--	--	--	BO
July 2	01° 36′ S.	81° 09′ W.	--	78	--	--	--	--	--	BB
1958										
Jan. 17	01° 50′ S.	81° 11′ W.	--	79	01° 28′ S.	81° 04′ W.	7	--	23	PS
Nov. 11	01° 15′ S.	81° 08′ W.	--	75	03° 31′ S.	81° 03′ W.	16	--	135	BB
Nov. 11	01° 15′ S.	81° 08′ W.	--	75	03° 48′ S.	81° 05′ W.	142	--	153	BO
1954	**Gulf of Guayaquil**									
Oct. 21	03° 13′ S.	81° 02′ W.	470	--	--	--	--	--	--	--
Oct. 21	03° 13′ S.	81° 02′ W.	480	--	03° 36′ S.	81° 15′ W.	18	485	20	BB
Nov. 14	03° 30′ S.	81° 10′ W.	515	72	--	--	--	496	--	--
Dec. 8	02° 28′ S.	81° 02′ W.	535	69	03° 31′ S.	80° 54′ W.	67	--	70	PS
Dec. 10	02° 28′ S.	81° 02′ W.	490	70	03° 30′ S.	81° 15′ W.	41	489	65	BB
1957										
Dec. 4	03° 30′ S.	81° 10′ W.	--	73.4	09° 05′ S.	79° 57′ W.	73	--	351	BB
1958										
Oct. 8	04° 15′ S.	81° 29′ W.	--	73.4	--	--	1–12	--	--	BB
Oct. 11	03° 42′ S.	80° 56′ W.	--	74.1	--	--	--	--	--	BB
Oct. 12	03° 24′ S.	81° 08′ W.	--	74.3	03° 25′ S.	81° 00′ W.	20	520	8	BB
Oct. 12	03° 24′ S.	81° 08′ W.	--	74.3	04° 05′ S.	81° 04′ W.	73	--	42	--

Oct. 13	03° 24′ S.	81° 12′ W.	--	74.3	03° 26′ S.	81° 01′ W.	33–44	--	11	BB
Oct. 13	03° 24′ S.	81° 12′ W.	--	74.3	03° 30′ S.	81° 10′ W.	52	--	6	BB
Oct. 13	03° 24′ S.	81° 12′ W.	--	74.3	04° 10′ S.	81° 23′ W.	185	--	41	BO
Oct. 18	04° 24′ S.	81° 42′ W.	--	71.2	09° 05′ S.	79° 57′ W.	23	--	296	BB
Oct. 18	04° 24′ S.	81° 42′ W.	--	71.2	03° 41′ S.	81° 00′ W.	55	--	63	--
Oct. 18	04° 34′ S.	81° 39′ W.	--	71.4	03° 28′ S.	81° 21′ W.	16	--	68	BB
Oct. 18	04° 34′ S.	81° 39′ W.	--	71.4	03° 26′ S.	81° 01′ W.	45	485	98	BB
Oct. 18	04° 34′ S.	81° 39′ W.	--	71.9	03° 34′ S.	80° 58′ W.	--	510	71	BB
Oct. 18	04° 34′ S.	81° 39′ W.	--	71.4	03° 56′ S.	81° 00′ W.	104	--	56	BO
Oct. 18	04° 34′ S.	81° 39′ W.	--	71.4	03° 22′ S.	81° 12′ W.	--	--	68	BB
Oct. 18	04° 34′ S.	81° 42′ W.	--	71.9	04° 34′ S.	81° 42′ W.	1	519	0	BB
Oct. 18	04° 34′ S.	81° 42′ W.	--	71.9	03° 00′ S.	81° 00′ W.	18		102	BB
Oct. 18	04° 34′ S.	81° 42′ W.	--	71.9	04° 15′ S.	81° 20′ W.	--	--	29	BO
Oct. 18	04° 34′ S.	81° 42′ W.	--	71.9	03° 17′ S.	80° 55′ W.	93	--	90	BB
Oct. 19	04° 10′ S.	81° 38′ W.	--	71.7	03° 23′ S.	80° 57′ W.	71	--	63	BB
Oct. 19	04° 10′ S.	81° 38′ W.	--	71.7	04° 09′ S.	81° 20′ W.	72	--	19	BO
Oct. 19	04° 10′ S.	81° 38′ W.	--	71.7	03° 49′ S.	81° 05′ W.	76	--	64	BO
Oct. 19	04° 10′ S.	81° 38′ W.	--	71.7	02° 17′ S.	81° 12′ W.	101	--	117	BB
Oct. 19	04° 10′ S.	81° 38′ W.	--	71.7	03° 22′ S.	81° 02′ W.	105	--	52	BO
Oct. 19	04° 12′ S.	81° 37′ W.	--	71.9	04° 15′ S.	81° 46′ W.	1	--	7	BB
Oct. 19	04° 12′ S.	81° 37′ W.	--	71.9	02° 50′ S.	80° 55′ W.	17	578	95	BO
Oct. 19	04° 12′ S.	81° 37′ W.	--	71.9	09° 04′ S.	79° 55′ W.	20	--	308	BO
Oct. 19	04° 12′ S.	81° 37′ W.	--	71.9	03° 32′ S.	81° 12′ W.	39	520	47	BO
Oct. 19	04° 12′ S.	81° 37′ W.	--	71.9	04° 05′ S.	81° 06′ W.	60	--	32	--
Oct. 19	04° 12′ S.	81° 37′ W.	--	71.9	03° 21′ S.	81° 12′ W.	75	570	52	BB
Oct. 19	04° 12′ S.	81° 37′ W.	--	71.9	03° 44′ S.	81° 00′ W.	106	--	11	BO
Oct. 19	04° 12′ S.	81° 37′ W.	--	71.9	04° 25′ S.	81° 22′ W.	146	--	20	BO
Oct. 19	04° 12′ S.	81° 37′ W.	--	71.9	03° 29′ S.	80° 49′ W.	--	--	63	BO
Oct. 19	04° 12′ S.	81° 37′ W.	--	71.9	--	--	-	490	--	BB
Oct. 19	04° 14′ S.	81° 36′ W.	--	71.7	03° 20′ N.	90° 50′ W.	45	490	720	BB
Oct. 19	04° 14′ S.	81° 36′ W.	--	71.7	04° 05′ S.	81° 06′ W.	62	--	31	--
Oct. 19	04° 14′ S.	81° 36′ W.	--	71.7	--	--	63	--	--	BB
Oct. 19	04° 14′ S.	81° 36′ W.	--	71.7	03° 34′ S.	80° 58′ W.	104	--	55	BO
Oct. 19	04° 14′ S.	81° 36′ W.	--	71.7	03° 54′ S.	81° 02′ W.	271	--	40	BO
Oct. 20	04° 10′ S.	81° 42′ W.	--	71.4	03° 00′ S.	80° 58′ W.	17	439	85	BB
Oct. 20	04° 10′ S.	81° 42′ W.	--	71.4	04° 05′ S.	81° 12′ W.	13–42	--	31	BO
Oct. 20	04° 10′ S.	81° 42′ W.	--	71.4	03° 32′ S.	81° 12′ W.	39–42	511	51	BB
Oct. 20	04° 10′ S.	81° 42′ W.	--	71.4	03° 57′ S.	81° 07′ W.	83–93	--	37	--
Oct. 26	02° 32′ S.	81° 03′ W.	--	72.3	03° 57′ S.	80° 59′ W.	108	--	85	BO
Oct. 27	02° 16′ S.	81° 10′ W.	--	71.7	03° 40′ S.	80° 56′ W.	40	--	85	BO
Oct. 27	02° 16′ S.	81° 10′ W.	--	71.7	04° 05′ S.	81° 07′ W.	58	--	115	--
Oct. 27	02° 16′ S.	81° 10′ W.	--	71.7	03° 49′ S.	81° 04′ W.	78	--	94	BO

APPENDIX B—Continued

Release and Recovery Data for 237 Skipjack Tags Returned, 1953 Through 1959

Release					Recovery					
Date	Latitude	Longitude	Fish length (mm.)	Surface temperature (degrees F.)	Latitude	Longitude	Days at liberty	Fish length (mm.)	Distance traveled (miles)	Recovery gear*
Oct. 27	02° 16′ S.	81° 10′ W.	--	71.7	03° 21′ S.	80° 52′ W.	82	--	67	BB
Oct. 27	02° 42′ S.	81° 10′ W.	--	71.6	03° 57′ S.	81° 07′ W.	76–86	--	75	BB
Oct. 27	02° 42′ S.	81° 10′ W.	--	71.6	03° 32′ S.	81° 12′ W.	--	--	52	BB
Oct. 31	03° 16′ S.	81° 01′ W.	--	73.0	03° 45′ S.	81° 02′ W.	24	--	29	BB
Oct. 31	03° 16′ S.	81° 01′ W.	--	73.0	03° 41′ S.	81° 15′ W.	--	--	29	BO
Oct. 31	03° 22′ S.	81° 01′ W.	--	72.1	03° 52′ S.	80° 56′ W.	35	--	26	BB
Oct. 31	03° 22′ S.	81° 01′ W.	--	72.1	03° 47′ S.	81° 05′ W.	68	--	26	--
Oct. 31	03° 22′ S.	81° 01′ W.	--	72.1	04° 10′ S.	81° 15′ W.	85	--	55	BO
Nov. 9	03° 41′ S.	81° 04′ W.	--	72.8	03° 28′ S.	81° 06′ W.	14	544	13	BB
1959										
Apr. 2	03° 32′ S.	81° 08′ W.	--	76.4	03° 21′ S.	80° 55′ W.	20	--	18	BO
1957	**Peru (North)**									
Dec. 22	09° 05′ S.	79° 52′ W.	--	72.5	09° 04′ S.	79° 56′ W.	15	--	4	BB
Dec. 22	09° 08′ S.	80° 00′ W.	--	73.0	09° 05′ S.	79° 57′ W.	22	--	4	BB
1958										
Jan. 10	09° 03′ S.	79° 57′ W.	--	74.7	09° 05′ S.	79° 57′ W.	21	--	2	BB
Jan. 10	09° 03′ S.	79° 57′ W.	--	74.7	--	--	--	--	--	BB
Jan. 11	09° 03′ S.	79° 57′ W.	--	74.3	01° 03′ S.	80° 59′ W.	134	--	497	--
Jan. 12	09° 03′ S.	79° 55′ W.	--	72.5	09° 04′ S.	79° 56′ W.	10	--	1	BB
Sept. 11	09° 13′ S.	79° 36′ W.	--	65.8	09° 00′ S.	79° 40′ W.	4	--	15	BB
Sept. 11	09° 13′ S.	79° 36′ W.	--	65.8	--	--	--	--	--	BB
Sept. 11	09° 13′ S.	79° 36′ W.	--	65.8	04° 12′ S.	81° 37′ W.	--	--	344	BO
Sept. 19	09° 12′ S.	79° 34′ W.	--	65.4	09° 04′ S.	79° 54′ W.	4	--	23	BB
Sept. 19	09° 12′ S.	79° 34′ W.	--	65.4	09° 04′ S.	79° 55′ W.	5	--	20	BB

Nov. 5	09° 05′ S.	79° 57′ W.	67.2	09° 05′ S.	79° 57′ W.	3	0	BB
Nov. 5	09° 05′ S.	79° 57′ W.	67.2	09° 05′ S.	79° 57′ W.	3–5	0	BB
Nov. 5	09° 05′ S.	79° 57′ W.	67.2	09° 05′ S.	79° 57′ W.	5	0	BB
Nov. 5	09° 05′ S.	79° 57′ W.	67.2	09° 05′ S.	79° 57′ W.	5	0	BB
Nov. 5	09° 05′ S.	79° 57′ W.	67.2	09° 05′ S.	79° 57′ W.	9	0	BB
Nov. 5	09° 05′ S.	79° 57′ W.	67.2	03° 10′ S.	80° 36′ W.	13	340	BB
Nov. 5	09° 05′ S.	79° 57′ W.	67.2	03° 32′ S.	81° 12′ W.	16	344	BB
Nov. 5	09° 05′ S.	79° 57′ W.	67.2	03° 32° S.	81° 12′ W.	16	344	BB
Nov. 5	09° 05′ S.	79° 57′ W.	67.2	03° 28′ S.	81° 06′ W.	7–19	330	BB
Nov. 5	09° 05′ S.	79° 57′ W.	67.2	03° 26′ S.	81° 01′ W.	10–21	378	BB
Nov. 5	09° 05′ S.	79° 57′ W.	67.2	03° 26′ S.	81° 01′ W.	10–21	378	BB
Nov. 5	09° 05′ S.	79° 57′ W.	67.2	03° 26′ S.	81° 01′ W.	10–21	378	BB
Nov. 5	09° 05′ S.	79° 57′ W.	67.2	03° 26′ S.	81° 01′ W.	10–21	378	BB
Nov. 5	09° 05′ S.	79° 57′ W.	67.2	03° 32′ S.	81° 12′ W.	12–23	372	BB
Nov. 5	09° 05′ S.	79° 57′ W.	67.2	03° 32′ S.	81° 12′ W.	12–23	372	BB
Nov. 5	09° 05′ S.	79° 57′ W.	67.2	09° 05′ S.	79° 57′ W.	28	0	BB
Nov. 5	09° 05′ S.	79° 57′ W.	67.2	03° 26′ S.	80° 57′ W.	30–47	355	BB
Nov. 5	09° 05′ S.	79° 57′ W.	67.2	03° 34′ S.	80° 58′ W.	33–71	358	BB
1959								
Apr. 4	09° 05′ S.	79° 57′ W.	76.5	03° 54′ S.	81° 02′ W.	104	322	BO
Apr. 5	09° 05′ S.	79° 57′ W.	76.5	00° 44′ S.	80° 57′ W.	192	525	BB
Apr. 6	09° 05′ S.	79° 57′ W.	76.6	04° 03′ S.	81° 09′ W.	122	335	PS
Apr. 7	08° 26′ S.	80° 14′ W.	76.5	01° 10′ S.	81° 05′ W.	166	461	BB
Apr. 9	09° 05′ S.	79° 57′ W.	76.5	09° 05′ S.	79° 57′ W.	1–5	0	BB
Apr. 9	09° 05′ S.	79° 57′ W.	76.5	04° 13′ S.	81° 05′ W.	101	345	BO
Apr. 9	09° 05′ S.	79° 57′ W.	76.5	03° 01′ S.	81° 01′ W.	140	388	BB
Apr. 9	09° 05′ S.	79° 57′ W.	76.5	03° 16′ S.	81° 01′ W.	114–145	373	PS
Apr. 9	09° 05′ S.	79° 57′ W.	76.5	03° 30′ S.	81° 01′ W.	133 or 159	350	BB
Apr. 10	09° 05′ S.	79° 57′ W.	76.5	03° 16′ S.	81° 01′ W.	115–145	373	BB
Apr. 10	09° 05′ S.	79° 57′ W.	76.5	03° 30′ S.	81° 10′ W.	141–145	360	BB
Apr. 10	09° 05′ S.	79° 57′ W.	76.5	Off Ecuador		86	450+	PS
Apr. 17	09° 05′ S.	79° 57′ W.	76.2	09° 05′ S.	79° 57′ W.	38–39	0	BB
Apr. 17	09° 05′ S.	79° 57′ W.	76.2	09° 05′ S.	79° 57′ W.	42	0	BB
Apr. 17	09° 05′ S.	79° 57′ W.	76.2	--	--	--	--	BB
Apr. 17	09° 05′ S.	79° 57′ W.	76.2	09° 05′ S.	79° 57′ W.	--	0	BB
Apr. 17	09° 05′ S.	79° 57′ W.	76.2	03° 33′ S.	81° 12′ W.	122	355	BB
Apr. 17	09° 05′ S.	79° 57′ W.	76.2	--	--	166–197	--	PS
Apr. 18	09° 05′ S.	79° 57′ W.	77.3	09° 05′ S.	79° 57′ W.	35	0	BB
Apr. 18	09° 05′ S.	79° 57′ W.	77.3	04° 05′ S.	81° 05′ W.	146	369	BO
Apr. 18	09° 05′ S.	79° 57′ W.	77.3	03° 28′ S.	80° 53′ W	147	372	BB

APPENDIX B—Continued

Release and Recovery Data for 237 Skipjack Tags Returned, 1953 Through 1959

Release					Recovery					
Date	Latitude	Longitude	Fish length (mm.)	Surface temperature (degrees F.)	Latitude	Longitude	Days at liberty	Fish length (mm.)	Distance traveled (miles)	Recovery gear*
1954	**Galapagos Islands**									
Feb. 22	00° 16′ N.	91° 37′ W.	490	71	00° 16′ N.	91° 37′ W.	5–7	486	0	BB
Dec. 20	01° 40′ N.	92° 00′ W.	500	--	01° 40′ N.	92° 00′ W.	17	502	0	BB
1955										
Apr. 2	00° 33′ S.	91° 21′ W.	505	76	00° 33′ S.	91° 21′ W.	6	487	0	BB
1957	**Cocos Islands**									
Feb. 28	05° 30′ N.	88° 34′ W.	560	83.1	05° 32′ N.	88° 31′ W.	47	--	2	BB

* PS-purse seiner, BB-bait boat, BO-bolichero, TR-troller.

APPENDIX C

Number of Pacific Yellowfin Tuna Tagged and Released by Area (One-Degree Square), Month and Year

One-degree square	Month of release	Year of release							
		1952	1953	1954	1955	1956	1957	1958	1959
28N-118W	Aug.		3						
28N-118W	Oct.			1					
27N-114W	Aug.							28	
27N-114W	Oct.	11							
27N-115W	Sept.							72	
27N-115W	Oct.	2							
26N-113W	Aug.							61	
26N-113W	Oct.	189							
26N-114W	July							185	
26N-114W	Aug.							47	
26N-115W	Oct.	64							
25N-110W	April		1						
25N-112W	June							22	
25N-112W	July							7	
25N-113W	July		7	3				1	
25N-113W	Aug.							177	
25N-113W	Sept.				40				
25N-113W	Oct.	11		1					
24N-111W	May							42	
24N-112W	June							38	
24N-112W	July					241			
24N-112W	Sept.			5	190				
23N-111W	May							299	
23N-111W	June		45					99	
23N-111W	July		104	7					
23N-111W	Sept.				153				
23N-112W	May							96	
23N-112W	June							20	
23N-112W	July		399						
23N-113W	July		29						
22N-106W	Nov.					6			
22N-108W	Feb.	2							
22N-110W	May		5						
22N-110W	June		13						
22N-111W	June		130					9	
22N-111W	July		160						
22N-112W	June		75						
22N-112W	July		44						
22N-113W	July		8						
21N-106W	Jan.						6		
21N-106W	May					2			
21N-106W	June					43	18		
21N-106W	July						87		
21N-106W	Nov.					38			
21N-106W	Dec.					16			
21N-108W	March	10							
21N-110W	May			1					
21N-110W	June		12						
20N-105W	Nov.					27			
20N-106W	Feb.	1							
20N-106W	May					2			
20N-106W	June					1	84		
20N-106W	July						6		
20N-106W	Nov.					12			
20N-107W	March						4		
19N-104W	April	4							
19N-105W	March	26							
19N-107W	June						3		
19N-111W	July					1			
19N-111W	Aug.					2			
19N-111W	Sept.				43				
19N-112W	May							99	
19N-112W	June		15						
19N-112W	July					9			
18N-103W	May						43		
18N-103W	June						6		

APPENDIX C—Continued

Number of Pacific Yellowfin Tuna Tagged and Released by Area (One-Degree Square), Month and Year

One-degree square	Month of release	Year of release							
		1952	1953	1954	1955	1956	1957	1958	1959
18N-104W	Feb.	7							
18N-104W	March		2						
18N-104W	April	1							
18N-104W	May		5				27		
18N-104W	June						16		
18N-107W	April					1			
18N-110W	May							13	
18N-111W	July					11			
18N-111W	Aug.					1			
18N-111W	Sept.				50				
18N-112W	July					6			
18N-112W	Aug.					1			
18N-114W	May							117	
18N-114W	June		120				8	60	
17N-101W	Feb.				67			27	
17N-101W	April	26							
17N-101W	June						115		
17N-102W	Feb.	17			168				
17N-102W	March				3				
17N-102W	April	188							
17N-102W	May						1		
17N-102W	Nov.				15				
17N-103W	Feb.				39				
17N-103W	March	8							
17N-103W	May		10						
17N-104W	Feb.				18				
17N-104W	May						2		
17N-105W	March					3			
17N-105W	April					5			
16N-98W	June						13		
16N-99W	Jan.				2	4	8		
16N-99W	Feb.				2				
16N-99W	March	39							
16N-99W	April						5		
16N-100W	Jan.					18	2		
16N-100W	Feb.	1			40				
16N-100W	March						6		
16N-100W	April						3		
16N-100W	May					3			
16N-101W	March						33		
16N-101W	April	15							
16N-101W	May		10				6		
16N-102W	March					24			
16N-102W	April	7				1			
16N-103W	March					3	2		
16N-103W	April					1			
15N-94W	March						23		5
15N-95W	March								17
15N-95W	May						18		
15N-97W	Feb.				29			5	
15N-97W	March				16	51			
15N-97W	April			77					
15N-98W	Feb.				20				
15N-98W	March				40				
15N-98W	April				57	3			
15N-99W	Feb.				33				
15N-99W	March					3			
15N-99W	April				8				
15N-99W	Nov.				10				
15N-100W	March					6			
15N-101W	March					39			
15N-102W	March					5			
14N-92W	April						2		
14N-92W	May						1		
14N-93W	March						6		
14N-93W	April		7						

APPENDIX C—Continued

Number of Pacific Yellowfin Tuna Tagged and Released by Area (One-Degree Square), Month and Year

One-degree square	Month of release	Year of release							
		1952	1953	1954	1955	1956	1957	1958	1959
14N-93W	May						1		
14N-94W	March						78		
14N-94W	April				69				
14N-95W	May						5		
14N-96W	Feb.						7		
14N-96W	April				16				
14N-97W	Feb.				5				
14N-97W	June						171		
14N-98W	Feb.				112				
14N-98W	March				5				
14N-100W	Feb.						9		
14N-101W	Feb.						9		
14N-101W	April					1			
13N-89W	April						34		
13N-90W	Feb.						54		
13N-90W	March						85		
13N-91W	March						33		
13N-92W	April				52				
13N-92W	May						1		
13N-93W	Feb.						12		
13N-93W	March						1		
13N-93W	April				28				
13N-93W	May						6		
13N-94W	Feb.						4		
13N-94W	April				133				
13N-95W	April		81						
13N-95W	May						1		
13N-96W	April		67		6				
13N-99W	Feb.			2					
13N-101W	Feb.			1					
12N-87W	April			1					
12N-87W	May						30		
12N-88W	March				11		1		
12N-88W	April				9				
12N-88W	May						16		
12N-88W	Oct.			40					
12N-89W	Jan.				4				
12N-89W	Feb.				3				
12N-89W	March						11		
12N-89W	April				38		18		
12N-90W	Jan.				9				
12N-90W	Feb.						17		
12N-90W	March						236		
12N-90W	April						20		
12N-91W	Feb.						31		
12N-91W	March				2				
12N-91W	April						14		
12N-92W	Feb.						251		
12N-92W	March						1		
12N-93W	Feb.			3			41		
12N-93W	March						40		
12N-110W	Oct.				4				
11N-86W	Jan.				38				
11N-86W	May						4		
11N-87W	Jan.				3				
11N-87W	March				91				
11N-87W	April			8					
11N-87W	Oct.			16					
11N-88W	March				51				
11N-88W	Oct.			7	14				
11N-89W	March				40				
11N-89W	April				12				
11N-90W	May						1		
11N-90W	Oct.				3				
11N-92W	Feb.						57		
11N-93W	Feb.						22		

APPENDIX C—Continued

Number of Pacific Yellowfin Tuna Tagged and Released by Area (One-Degree Square), Month and Year

One-degree square	Month of release	Year of release							
		1952	1953	1954	1955	1956	1957	1958	1959
10N-86W	Jan.							150	
10N-86W	Feb.		1		27				
10N-86W	March			139				1	31
10N-86W	April			12					
10N-86W	May			37			29		
10N-86W	July						7		
10N-86W	Oct.			5					
10N-91W	May						11		
10N-109W	Jan.						2		
10N-109W	Feb.						6		
10N-109W	May						24		
10N-109W	Oct.				18				
09N-85W	Jan.				2			5	
09N-85W	Feb.				6		1		
09N-85W	March						4	1	15
09N-85W	April			3					
09N-85W	May						7		
09N-85W	Sept.			48					
09N-86W	Oct.			6					
09N-88W	Oct.				1				
08N-79W	Feb.				1				
08N-83W	Feb.				61				
08N-83W	Oct.			23					
08N-83N	Nov.			6					
08N-84W	Jan.				4				
08N-84W	March						67		
08N-84W	Oct.			12					
08N-85W	March				2				
08N-85W	April			89					
07N-77W	Feb.			2					
07N-77W	April			8					
07N-78W	March			6					
07N-78W	June						77		
07N-79W	Feb.				137				
07N-80W	Feb.				2				
07N-81W	Jan.				5				
07N-81W	March						3		
07N-81W	July						2		
07N-82W	Jan.				7				
07N-82W	Feb.				2				
07N-82W	April			3					
07N-82W	July						15		
07N-83W	March			4					
07N-84W	Jan.				1				
07N-84W	Feb.						6		
07N-86W	March				12				
06N-77W	Jan.		6						
06N-77W	Feb.							2	
06N-77W	June						202		
06N-78W	March			14					1
06N-78W	June						5		
06N-79W	July						3		
06N-82W	March								4
06N-83W	Jan.		37						
06N-84W	March			1					
06N-86W	March				2				
05N-77W	Jan.		2						
05N-77W	Feb.							12	
05N-77W	March								1
05N-77W	June						11		
05N-78W	Feb.							4	
05N-78W	March								15
05N-80W	July						14		
05N-82W	June						6		
05N-87W	Feb.						7		
05N-88W	Feb.						43		
05N-88W	March				21		3		

APPENDIX C—Continued

Number of Pacific Yellowfin Tuna Tagged and Released by Area (One-Degree Square), Month and Year

One-degree square	Month of release	Year of release							
		1952	1953	1954	1955	1956	1957	1958	1959
04N-78W	March								2
04N-80W	July						5		
04N-86W	Feb.			4					
03N-81W	March			7					
03N-90W	Feb.						3		
03N-90W	March			21	16				
02N-78W	Jan.		14						
02N-78W	May			11					
02N-79W	Jan.		60						
02N-79W	Feb.						1		
02N-79W	May			147					
02N-79W	Dec.	58							
02N-91W	March				11				
02N-91W	Sept.			10					
01N-79W	Jan.		472						
01N-79W	Feb.						14		
01N-79W	May			5					
01N-79W	Dec.	76							
01N-81W	Dec.	2							
01N-90W	March				1				
01N-91W	Feb.			125			48		
01N-91W	March			148	13				
01N-91W	Sept.			5					
01N-91W	Dec.	38		12					
01N-92W	March				41				
01N-92W	Nov.	7							
01N-92W	Dec.	71		33					
00N-80W	Jan.		8						
00N-90W	March			11					
00N-91W	Feb.			151					
00N-91W	March			295					
00S-80W	March								3
00S-89W	March			2					
00S-90W	Nov.	2							
00S-90W	Dec.			5					
00S-91W	March			22	11				
00S-91W	April				118				
01S-81W	Jan.							24	
01S-81W	May			76					
01S-81W	July						2		
01S-81W	Dec.	2							
01S-89W	Nov.	1							
01S-91W	Nov.	1							
02S-81W	July						1		
02S-81W	Oct.							2	
02S-81W	Dec.			48					
03S-80W	Oct.			4				19	
03S-80W	Nov.			331					
03S-80W	Dec.	46		41					
03S-81W	Jan.		12						
03S-81W	April								6
03S-81W	Oct.			81				89	
03S-81W	Nov.	156		9			46	43	
03S-81W	Dec.	67					36		
04S-81W	Oct.							44	
09S-79W	Jan.							81	
09S-79W	April								6
09S-79W	Sept.							10	
09S-79W	Nov.							75	
09S-79W	Dec.						81		
09S-80W	Dec.						22		
19S-70W	Dec.						3		
20S-70W	Jan.							24	
20S-70W	Dec.						43		
Totals	--	1156	1964	2195	2356	581	2745	2110	106

APPENDIX D

Number of Skipjack Tagged and Released by Area (One-Degree Square), Month and Year

One-degree square	Month of release	Year of release							
		1952	1953	1954	1955	1956	1957	1958	1959
30N-119W	Sept.			2					
28N-115W	Aug.							12	
28N-116W	Aug.			1					
28N-121W	Aug.		2						
27N-114W	July							11	
27N-114W	Aug.							3	
27N-114W	Oct.	10							
27N-115W	Sept.							119	
27N-115W	Oct.	1							
27N-120W	Aug.		2						
26N-113W	June							9	
26N-113W	Aug.							207	
26N-113W	Oct.	24							
26N-114W	July							457	
26N-114W	Aug.							24	
26N-115W	Oct.	17							
25N-112W	June							9	
25N-112W	July							18	
25N-113W	July		43					73	
25N-113W	Aug.							273	
25N-113W	Sept.				9				
25N-113W	Oct.	23							
24N-111W	May							53	
24N-112W	June							49	
24N-112W	July					169			
24N-112W	Sept.			5	105				
24N-115W	July					1			
23N-109W	Nov.					70			
23N-111W	May							30	
23N-111W	June							16	
23N-111W	July		68	4					
23N-111W	Sept.				51				
23N-112W	May							123	
23N-112W	June							14	
23N-112W	July		123			216			
23N-113W	July		69						
22N-106W	Nov.					18			
22N-106W	Dec.					49			
22N-108W	Feb.	1							
22N-110W	June		2						
22N-111W	June		70						
22N-111W	July		39						
22N-112W	June		88						
22N-112W	July		21						
22N-113W	July		67						
21N-105W	Nov.					17			
21N-106W	May					6			
21N-106W	June					62			
21N-106W	Nov.					237			
21N-106W	Dec.					99			
21N-110W	June		50						
21N-111W	June		3						
20N-105W	Nov.					275			
20N-106W	June					2			
20N-106W	Nov.					46			
19N-106W	April					14			
19N-110W	April					2			
19N-111W	July					82			
19N-111W	Aug.					180			
19N-112W	May							111	
19N-112W	July					37			
19N-112W	Aug.					33			
18N-105W	April					9			

APPENDIX D—Continued

Number of Skipjack Tagged and Released by Area (One-Degree Square), Month and Year

One-degree square	Month of release	Year of release							
		1952	1953	1954	1955	1956	1957	1958	1959
18N-105W	May					4			
18N-106W	April					38			
18N-107W	April					1			
18N-110W	May							3	
18N-111W	July					196			
18N-111W	Aug.					125			
18N-111W	Sept.				1				
18N-112W	July					73			
18N-112W	Aug.					70			
18N-114W	May							7	
18N-114W	June		4					12	
17N-101W	Nov.				1				
17N-103W	May		2			5			
17N-104W	April					2			
16N-100W	May					29			
16N-101W	April					4			
16N-101W	May		21			17			
16N-102W	March					13			
16N-102W	April					8			
16N-102W	May					4			
16N-103W	April					3			
16N-103W	May					9			
15N-97W	March					8			
15N-98W	April					1			
15N-100W	April					1			
15N-101W	March					11			
15N-101W	April					34			
15N-101W	May					18			
15N-102W	May					13			
15N-106W	Feb.			7					
14N-94W	April				18				
13N-89W	April						9		
13N-90W	Feb.						2		
13N-90W	March						12		
13N-91W	March						5		
13N-95W	April		45						
13N-96W	April		16						
13N-97W	Feb.			1					
13N-101W	Feb.			2					
12N-87W	May						5		
12N-87W	Sept.			73					
12N-88W	May						1		
12N-88W	Oct.			18					
12N-89W	March						1		
12N-89W	April						6		
12N-90W	March						36		
12N-91W	Feb.						7		
12N-91W	April						1		
12N-92W	Feb.						37		
12N-93W	Feb.			5			8		
12N-93W	March						9		
11N-87W	April			52					
11N-87W	Sept.			41					
11N-87W	Oct.			33					
11N-88W	Oct.			13					
11N-92W	Feb.						10		
11N-93W	Feb.						12		
10N-85W	Sept.			25					
10N-86W	Jan.							26	
10N-86W	Feb.		1		1				
10N-86W	March			16					4
10N-86W	April			12					
10N-86W	May			17			119		

APPENDIX D—Continued

Number of Skipjack Tagged and Released by Area (One-Degree Square), Month and Year

One-degree square	Month of release	Year of release							
		1952	1953	1954	1955	1956	1957	1958	1959
10N-86W	July						23		
10N-86W	Oct.			42					
10N-91W	May						4		
10N-109W	Oct.				1				
09N-84W	May						1		
09N-85W	Feb.				1				
09N-85W	April			3					
09N-85W	Sept.			25					
08N-83W	Feb.				10				
08N-83W	Oct.			50					
08N-83W	Nov.			11					
08N-84W	Oct.			55					
08N-85W	March			1	6				1
08N-85W	April			20					
07N-78W	June						92		
07N-79W	Feb.				6				
07N-81W	Jan.				3				
07N-82W	Jan.		2		4				
07N-82W	Feb.				1				
07N-82W	July						4		
07N-83W	Jan.							1	
07N-83W	March			10					
07N-84W	Feb.						5		
07N-84W	March			3					
07N-85W	March			6					
07N-86W	March				5				
07N-88W	Oct.				1				
06N-77W	Jan.		23						
06N-77W	June						63		
06N-78W	March			11					
06N-79W	July						3		
06N-83W	Jan.		10						
06N-83W	June						12		
06N-84W	March			3					
06N-85W	March			21					
06N-86W	March				8				
05N-77W	Feb.							5	
05N-77W	March								3
05N-77W	June						27		
05N-80W	July						2		
05N-82W	June						6		
05N-86W	Jan.				2				
05N-88W	Feb.						20		
04N-88W	March				58		1		
05N-78W	June						2		
04N-80W	July						1		
04N-81W	June						2		
03N-78W	Feb.						2	2	
03N-81W	March			6					
03N-90W	March			3	17				
02N-78W	Jan.		10						
02N-78W	May			28					
02N-79W	Jan.		24						
02N-79W	Feb.						3		
02N-79W	May			112					
02N-79W	Dec.	13							
02N-91W	March				2				
02N-91W	Sept.			2					
01N-79W	Jan.		20						
01N-79W	Feb.						10		
01N-79W	May			15					
01N-79W	Dec.	3							
01N-90W	March				36				

APPENDIX D—Continued

Number of Skipjack Tagged and Released by Area (One-Degree Square), Month and Year

One-degree square	Month of release	Year of release							
		1952	1953	1954	1955	1956	1957	1958	1959
01N-91W	Feb.			11					
01N-91W	March			105	173				
01N-91W	Sept.			7					
01N-91W	Nov.	17							
01N-91W	Dec.	43		81					
01N-92W	March				174				
01N-92W	Dec.	62		14					
00N-80W	Jan.		1						
00N-89W	Feb.						3		
00N-90W	March			15					
00N-90W	Nov.	3							
00N-91W	Feb.			70					
00N-91W	March			146					
00N-91W	Nov.	1							
00S-80W	Jan.		3						
00S-80W	March								4
00S-80W	June						20		
00S-89W	March			1					
00S-89W	Dec.			193					
00S-90W	Nov.	11							
00S-91W	March			116	38				
00S-91W	April				278				
00S-91W	Nov.	2							
01S-81W	Jan.		1					270	
01S-81W	May			370					
01S-81W	June						3		
01S-81W	July						156		
01S-81W	Nov.							23	
01S-81W	Dec.	29							
01S-89W	Nov.	22							
01S-90W	March			1					
01S-91W	Feb.			79					
01S-91W	March			107					
02S-81W	May			76					
02S-81W	July						42		
02S-81W	Oct.							95	
02S-81W	Dec.			89					
03S-80W	Oct.			31				110	
03S-80W	Nov.			515				3	
03S-80W	Dec.	71		114					
03S-81W	Jan.		1						
03S-81W	Feb.			44					
03S-81W	April								14
03S-81W	Oct.			292				95	
03S-81W	Nov.	47		31			39	14	
03S-81W	Dec.	76					94		
04S-81W	Feb.			4					
04S-81W	Oct.							244	
08S-80W	April								106
08S-80W	Sept.							8	
09S-79W	Jan.							69	
09S-79W	April								1331
09S-79W	Sept.							616	
09S-79W	Nov.							83	
09S-79W	Dec.						53		
09S-80W	Sept.							27	
09S-80W	Dec.						32		
11S-78W	Jan.							2	
19S-70W	Dec.						142		
20S-70W	Jan.							45	
20S-70W	Dec.						327		
Totals	--	509	831	3266	1010	2311	1474	3401	1463

NOTE

Toxicity of Tricon Oil Spill Eradicator to Striped Bass *(Roccus saxatilis)*

Tricon Oil Spill Eradicator is a commercial product designed to emulsify oil spilled on water. The manufacturer lists the composition as 20 percent petroleum sulfonate, 5 percent fatty acid esters, 10 percent polyethylene glycol ether, 63 percent petroleum solvents, and 2 percent alcohol.

The use of Tricon Oil Spill Eradicator has been proposed in waters of the San Francisco Bay area. Since these waters are inhabited by striped bass, the California Department of Fish and Game conducted bioassays in early 1957, in order to determine this eradicator's toxicity to this species.

Five striped bass were placed in each of eight aquaria containing 7,500 ml. of a mixture of water taken from the San Joaquin River at Antioch and various amounts of oil spill eradicator. For a control, five bass were placed in a ninth aquarium with 7,500 ml. of river water. The bass used ranged from 2.7 to 4.3 inches and averaged 3.4 inches in fork length. Air was bubbled slowly through the water in all aquaria; water temperature was maintained at approximately 65 degrees F.

The results were as follows:

Percentage concentration of Tricon Oil Spill Eradicator	Survival		Remarks
	Elapsed time	Number of bass alive	
2.0	7 minutes	0	All fish showed immediate distress.
0.1	6 minutes	0	All fish showed immediate distress.
0.05	8 minutes	0	All fish showed immediate distress.
0.005	30 minutes 1 hour	2 0	All fish showed distress after about one minute.
0.0016	1 hour 2 hours 3 hours 4 hours 5 hours	5 3 2 1 0	Fish started showing irritation after several minutes.
0.001	4 hours 5 hours 6 hours 8 hours 9 hours 10 hours	5 3 2 2 1 0	Fish showed first signs of distress at 1½ hours.
0.0005	48 hours	5	Fish showed no distress.
0.0005	48 hours	5	Fish showed no distress.
Control	48 hours	5	Fish showed no distress.

These results show clearly that Tricon Oil Spill Eradicator is toxic to striped bass at low concentrations. It is probable that lethal concentrations would occur at least locally, if the eradicator were used to treat oil spills.—*Harold K. Chadwick, California Dept. of Fish and Game, January, 1960.*

NOTE

A Range Extension of the California Halibut *(Paralichthys californicus)*

On November 10 or 11, 1959, Mr. Jim Riley, skipper of the trawler *INA*, was fishing for English sole *(Parophrys vetulus)* and petrale sole *(Eopsetta jordani)* in 30 to 35 fathoms of water four to six miles north of Redding Rock. While sorting his catch, he discovered a fish he believed was a California halibut. He turned it over to me and asked me to verify his identification.

It was taken to Eureka Marine Resources Laboratory where positive identification was made (counts and measurements are listed in Table 1). This proved a substantial northerly extension of the previous known range, Tomales Bay (Roedel, 1953).

TABLE 1

Meristic Counts and Measurements From a Left-eyed *Paralichthys californicus* Taken Off Redding Rock, November 1959

Measurements:*	
Standard length	370.0
Total length	116.2
Head length	19.9
Snout length	5.7
Orbit width	2.7
Maxillary length	10.5
Body depth	41.1
Counts:	
Dorsal rays	72
Anal rays	56
Ventral rays: right	6
left	6
Pectoral rays: right	12
left	12
Principal caudal rays	17
Gill rakers: lower limb	20
upper limb	9

* Standard length given in millimeters; all other measurements presented as percentages of standard length.

A California halibut was reported from this area on January 23, 1952, when a fish and game warden told biologist R. B. McCormick one had been caught by the trawler *DOROTHY ANN* off the mouth of the Klamath River. This was confirmed by Ray Hamblock, manager of the Balesteri Fish Company. He stated that the fish weighed 24 pounds. It was no longer available so McCormick could not make a positive identification.

On August 30, 1954, while making a sportfish survey at Buhne's Point (Humboldt Bay), McCormick recorded a California halibut that

had been taken by a sportsman while drift fishing for salmon at the mouth of the bay. Positive identification was made by McCormick. Measurements and fin counts were taken, but unfortunately this information was lost during a move. Photos of the fish on file at the Eureka laboratory indicate it was approximately 42 inches long.

On August 15, 1959, biologist Dan Gotshall was informed by a sportsfisherman that a California halibut had been taken at Shelter Cove (Humboldt County). Gotshall contacted the fisherman, Ralph L. Reese, but the fish was not available so Mr. Reese sent photos to substantiate the validity of the report.

REFERENCE

Roedel, Phil M.
1953. Common ocean fishes of the California coast. Calif. Dept. Fish and Game, Fish Bull. 91. 184 pp., 175 figs.

E. G. Gunderson, Marine Resources Operations, California Department of Fish and Game, January, 1960

REVIEWS

Oceanagraphy and Marine Biology

By H. Barnes; The Macmillan Co., New York, 1959; 218 pp., 110 figs. 35 shillings.

This is a book of techniques. It is designed to inform the reader how knowledge of the sea and of some of its inhabitants is obtained. It is written in a simple straightforward style making it easy for a beginner to decide what instruments may best suit his needs.

A primary concern is with the problems involved in making observations and measurements in the ocean. This is one of the few times that the scattered accounts of equipment and techniques used in oceanography and marine biology have been assembled under one cover—this alone makes the book a welcome addition to the literature.

A book of this scope necessarily involves fairly detailed descriptions of gear and methods; subjects that ordinarily make dull reading for all except the professional worker. Dr. Barnes succeeds in holding the reader's interest, however, by frequently inserting into the gear descriptions discussions of applications, results, and limitations; and by the liberal use of drawings and photographs.

It resembles a handbook and is divided into four major sections: the first deals with methods and gear used for sampling living pelagic organisms, except fish, and those that live on and within the ocean bottom sediments; the second section describes the use of shipboard sound waves in relation to fisheries, and includes a discussion of underwater noises produced by various species of fish; the third is concerned with properties of the water itself, but is limited to temperature, salinity, and current measurments; and the last section relates both aerial and underwater photography to fisheries problems.

Dr. Barnes also has included nine pages of references, which will prove of considerable value to anyone interested in oceanography and marine biology techniques. —*Harold B. Clemens, California Department of Fish and Game.*

Natural Resources

By Martin R. Huberty and Warren L. Flock; McGraw-Hill Book Company, Inc., New York, 1959; xviii + 556 pp., $11.

This book was written as a textbook in natural resources study for use by engineering students at the university level. As such, it compiles within its 556 pages a tremendous wealth of knowledge and profound thought regarding both our renewable and nonrenewable resources.

Leading authorities have each written chapters covering their respective fields. Examples are: Marine Resources, Milner Schaefer and Roger Reville; Ecology and Wildlife, Walter P. Taylor; and Forest Land and Forest Products, John A. Zivnuska.

The chapter on marine resources is of especial interest to biologists. All uses of the ocean environment are considered from recreation and waste disposal to water supply. Emphasis is placed on the fact that we currently harvest only a small fraction of the organic production of the sea.

"The challenge of new fields to conquer is clearly shown when we consider that the major fisheries are for the same kind of organisms that have been exploited since man first went to sea, that is, those whose aggregation habits make them amenable to large scale capture by the traditional kinds of gear."

Regarding human consumption of marine food products, it was surprising to learn that in the United States it has not increased on a per capita basis during the past 20 years despite improved refrigeration, transportation and retail marketing facilities. Certain specific marine food items have increased, but at the expense of others.

The author does not anticipate the use of lower levels of the marine food chain to be economically profitable for many years. A similar prognostication is made for farming the sea in a manner analogous to agriculture except for the shellfish.

Many sage comments are found throughout the book such as this one: "There is a very great need for thorough studies, combining economics and the natural sciences of marine resources in order to develop a more rational basis for their exploitation."

Other chapters are equally informative. The biologist as well as the physical scientist will find this volume most useful as a means of broadening his background information on our natural resources and their uses. It will serve also as a handy reference.—*Willis A. Evans, California Department of Fish and Game.*

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